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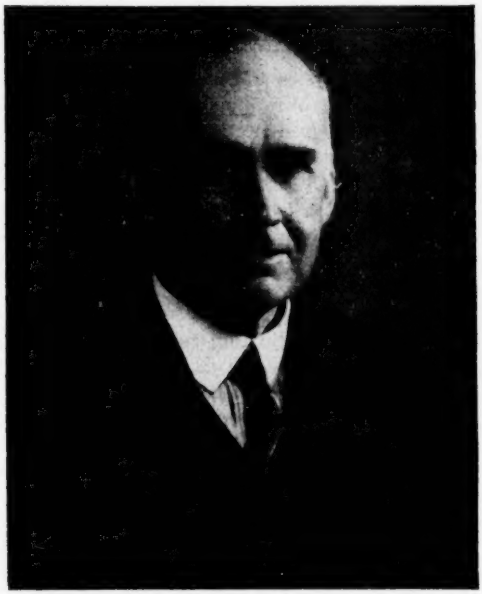
Sir Arthur Eddington--Pioneer of Stellar Research 1882-1944

By HERBERT DINGLE*

Sir Arthur Stanley Eddington occupied a unique place in British—indeed in world—astronomy, and his unexpected death on November 22, 1944, leaves a gap which is likely to remain unfilled for many years to come. His special position resulted from the fact that in him the astronomer, the physicist, and the mathematician were blended, in equal



Photograph by Bassano, Ltd.

SIR ARTHUR EDDINGTON

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and abundant measure, by a naturally philosophic mind. Such men are rare and at the present time, when all departments of science are advancing at such a speed, the need for them is urgent.

Moreover, Eddington's chief work was left unfinished. The synthesis of the physical sciences which he set himself to construct was but partly developed at the time of his death, and it took a form so strange to most of his contemporaries that they had not succeeded in grasping its essential characer. That he should have been taken from us while his contribution to knowledge was so incomplete is a tragedy difficult to measure.

Eddington was born at Kendal, Westmorland, in the famed English Lake District, on December 28, 1882. His father was headmaster of the Friend's School there, and young Eddington was brought up in the spiritual atmosphere of the Society of Friends, that small body which has contributed so much to the best elements of both English and American life. His early education was received at Weston-super-Mare, in Somerset, where the family moved after the death of his father, and from there he proceeded to Owen's College, Manchester, and afterwards to Trinity College, Cambridge, at which Institutions he received a thorough grounding in physics and mathematics.

In 1904 he became Senior Wrangler at Cambridge, the highest distinction possible to a young graduate in mathematics at that university, and after a brief period of research in physics in the Cavendish laboratory he was appointed Chief Assistant at the Royal Observatory, Greenwich. From then onwards, astronomy stood in the forefront of Eddington's interests, and it was through this, the most universal of sciences, that he approached the great problems with which he was later to deal.

His early work consisted of necessity of some practical routine operations, chiefly with the Cookson floating zenith telescope, an instrument whose chief purpose was the accurate determination of the constant of aberration and the variation of latitude. He was essentially, however, a theoretical investigator, although he had a much stronger practical sense than most workers of that type, and he naturally turned to what at that time was the most general and comprehensive department of astronomy—the problem of stellar movements.

Kapteyn had shortly before made his discovery of star-streaming, and for the first time a proper study of the stellar system as a dynamical system had become possible. This was a subject made for Eddington's mind, and his contributions were of such quality that when the Plumian Professorship of Astronomy and Experimental Philosophy at Cambridge became vacant through the death of Sir George Darwin, he was appointed in 1913 to the position, and in the following year was elected also to the Directorship of the University Observatory in succession to Sir Robert Ball. He resided, in fact, at the Observatory with his only sister from that time until his death.

Shortly after his return to Cambridge Eddington's first book was published—"Stellar Movements and the Structure of the Universe." In this he summed up the results of his own work and that of others in the subject which he seemed to have made his own. "So far as practicable," he wrote, "I have endeavored to write for the general scientific reader." He gave, indeed, the first example of writing which was to become characteristic of him—a delightfully readable account of researches of the deepest and most difficult problems from which both the specialist and the layman could derive pleasure and profit.

"The knowledge that progress will inevitably lead to a readjustment of ideas," he wrote, "must instil the writer with caution; but I believe that excessive caution is not to be desired. There can be no harm in building hypotheses, and weaving explanations which seem best fitted to our present partial knowledge. These are not idle speculations if they help us, even temporarily, to grasp the relations of scattered facts, and to organize our knowledge." This also was a characteristic attitude. He was a mental adventurer, avoiding risk if safe progress was possible, but never deterred by fear of getting lost from exploring promising new country without a compass.

Although further work on stellar movements followed the publication of this book, it was not long before very different problems were to engage Eddington's attention. The first of these was concerned with the internal constitution of the stars—a subject which, despite a few earlier pioneer papers by others, he may properly be said to have recognized for the first time in the field of astronomy as a large and important area of investigation. The mathematician had found scope in stellar dynamics; it was time for the physicist to declare himself. Eddington saw that the interior of a star must be a region ripe for the application of recent physical knowledge, and he therefore set himself to consider the general problem of the equilibrium of gaseous material at high temperatures.

In the earlier, partial attacks on this problem, the effects of radiation inside the star had been ignored. Eddington saw that they would be predominant both in transferring energy from the interior to outer space and also, through radiation pressure, in supporting the weight of the outer layers of the star. His calculations showed, in fact, that with bodies so massive as stars there would be a limiting mass beyond which radiation would be so intense that the material could no longer exist as a single body, but would be disintegrated. Further, there was also a lower limit beyond which the radiation would be too weak for the body to be visible. It was one of the strong points of Eddington's theory that these limits were approximately identical with the limiting values of known stellar masses. He thus for the first time gave a reasonable explanation of the fact, so familiar as usually to fail to excite wonder, that the visible material universe is broken up into almost innumerable spheres lying within a very narrow range of mass.

Further developments of the theory are too numerous to be described here. Many of them are summed up in his well-known book, "The Internal Constitution of the Stars" (1926), which is still indispensable to workers in this subject. One consequence, however, is too important to be passed over in even the briefest summary. The theory required that if a star could be regarded as a perfect gas, its mass should bear a certain definite relation to its luminosity. In 1924, Eddington tested this requirement with the scanty data then available, and found that it was confirmed with embarrassing thoroughness. At that time it was believed that giant stars were virtually perfect gases but dwarf stars were not—that, in fact, they were distinguished from giants by this very difference. Eddington found, however, that dwarfs and giants alike obeyed his mass-luminosity relation. He was not long in finding the explanation.

At the temperatures of stellar interiors the atoms are so stripped of their outer electrons as no longer to exist at atoms but only as separate positive and negative charges which move about independently of one another. In these circumstances, extremely high densities are possible, for the charges, not now having to confine themselves to configurations, can move almost indefinitely close to one another. The condition of an ordinary dwarf star then, in which the density was comparable with that of a terrestrial liquid, corresponded, so far as its equation of state was concerned, to a perfect gas, for the size of its particles was negligible compared with that of the "white dwarfs," in which the parts even of disintegrated atoms occupied an appreciable fraction of the total volume of the star. The densities of such stars should be excessively high, far beyond anything possible with normal atoms and, in fact, such densities had appeared previously to belong to these stars but had been rejected as impossible. Eddington's work, therefore, not only confirmed, but also explained, this apparently deceptive observation.

One of the most remarkable features of Eddington's career is the continuity of its progress, from which one would never guess that almost at its beginning the most revolutionary event in his whole mental development occurred, which, as he said, changed the character of his outlook. This was his introduction to Einstein's general theory of relativity which, appearing during World War I, had made a belated arrival in England at the end of 1916 through some papers by de Sitter communicated to the Royal Astronomical Society. Eddington immediately mastered what for the great majority of his contemporaries was an almost complete mystery, and became at once not only the leading English exponent of the theory but also a contributor to its further development.

In May, 1919, an eclipse of the sun was to occur, almost incredibly favorable for testing the prediction of Einstein's theory concerning the bending of rays of light in a gravitational field. Notwithstanding the war then raging in Europe, which showed little prospect of ending in

time for this test to be made, Eddington, with Sir Frank Dyson, then Astronomer Royal, made all the necessary preparations for sending expeditions to Brazil and West Africa in order to seize the opportunity. The war ended with unexpected suddenness, and the expeditions set out. Eddingon went to Principe, off the West coast of Africa, but met with only partially favorable weather. The other expedition had a clear sky in Brazil, and the net result was a confirmation of Einstein's prediction which, despite criticisms, still remains a valuable part of the evidence of general relativity.

In astronomy proper, Eddington was usually a pioneer. One of the most interesting of his new ideas was that of the inter-stellar cosmic cloud, which he first introduced in the Royal Society Bakerian Lecture of 1926. Stationary H and K lines of ionized calcium in the spectra of certain stars had been observed on several earlier occasions, and tentative explanations had been offered in terms of hypothetical clouds of matter surrounding stars of the affected types. The new idea which Eddington introduced was that the cloud was universal, filling the whole of inter-stellar space, and that the absorption appeared only with certain types of stars because only those types were sufficiently bright to give observable spectra at distances allowing observable absorption. From the data available—soon afterwards increased through observations by Plaskett and Pearce—he was able to calculate the density and temperature of the cloud and to show that, despite its extreme tenuity, it nevertheless accounted for a considerable fraction of the total mass of the universe.

Mention of the universe brings one inevitably to the dominating ambition of Eddington's life—the construction of a theory which would co-ordinate the basic ideas of physics and astronomy into complete representation of the physical universe. His work on relativity had led him to see in the "cosmic constant," which Einstein originally introduced into the mathematical expression of the law of gravitation in order to deal with difficulties at infinity, a fundamental "constant of nature"—that is to say, a constant demanded not merely by the actual constitution of the universe, but by the fundamental nature of things, and therefore significant no matter how the universe might happen to be constructed. Physicists, however, had been piercing to the roots of nature by different means, and had arrived at the quantum theory, which also described "the fundamental nature of things," but in other terms—those commonly described as the properties of electrons and such elementary particles. According to Eddington, the two descriptions must be equivalent, and he undertook the task of harmonizing them. He believed that in these most generalized achievements of science we had penetrated not merely to the characteristics which distinguished the actual universe from all other possible universes, but to the necessary conditions which any conceivable universe must satisfy.

This is equivalent to the postulate that these so-called "laws of

nature" are, in fact, "laws of thought," derivable by a sufficiently powerful intelligence from the necessary conditions of thinking and not merely from observation of the particular physical world which, in our experience, exemplifies them. He claimed to have derived the dimensionless "constants of nature"—combinations of cosmic and quantum constants whose values are independent of our arbitrary units of measurement—by pure reason, without making any demands on the results of actual measurements.

In this work, which he regarded as his supreme achievement, Eddington did not succeed in making his ideas understood by his colleagues. Despite his great gift for lucid exposition, to which many owe their first clear view of the meaning of difficult physical conceptions, this work of his remains for most a secret, and, not unnaturally, there is a widespread belief that it is the product of an illusion. Perhaps, however, it would be wiser to postpone a decision. There seems little doubt that in some of his attempts to make his meaning clear he allowed himself to make untenable assertions, but it does not at all follow that he had not reached conclusions of very great importance which the passage of time will reveal in more generally intelligible form.

Eddington was a man of quiet, reserved temperament, not easy to get to know, but impossible not to love, respect, and admire when one did know him. His reputation in the astronomical world was very high indeed, and at the time of his death he was President of the International Astronomical Union. He received many honors, outstanding among which were a knighthood in 1930 and, in 1938, the reward of the Order of Merit, the supreme British testimony to intrinsic intellectual worth. He was well-known among American astronomers, and made several visits to the United States and Canada for lecturing and other purposes. Many will remember his lecture at Cambridge, Mass., in September, 1932, during the meeting of the International Astronomical Union, which was later published in an expanded form as a book, "The Expanding Universe."

London, England, April, 1945.

The Cosmogonical Significance of Stellar Rotation

By OTTO STRUVE

(Continued from page 218)

IV. Rotational Instability

The gravitational acceleration at the surface of a star is

$$g_1 = 2.74 \times 10^4 \, (M/R^2),$$

where the mass M and the radius R are expressed in units of the sun. The acceleration caused by the centrifugal force is

$$g_2 = v^2/R = 1.44 \times 10^{-11} \, (v^2/R).$$

To have rotational instability we must have

$$g_2 \geqslant g_1.$$

Setting

$$g_1 = g_2$$

we have

$$2.74 \times 10^4 \, (M/R^2) = 1.44 \times 10^{-11} \, (v^2/R), \text{ if v is in cm/sec}$$

or

$$2.74 \times 10^4 \, (M/R^2) = 1.44 \times 10^{-1} \, (v^2/R), \text{ if v is in km/sec.}$$

Hence, the limiting equatorial velocity is

$$v = 4.4 \times 10^2 \sqrt{(M/R)}.$$

For the sun $v = 440$ km/sec. We proceed to compute this for different values of M and R. If we recall that the mass-luminosity relation gives us

$$m_{bol} + 2 \log (T/5200°) = f (\log M)$$

where m_{bol} is the absolute bolometric magnitude, and that, moreover, the luminosity of the star

$$L = 4\pi R^2 \sigma T^4$$

we can express the break-up velocities v as functions of m_{bol} and T. This has been done in Figure 6, where the dotted lines show the approximate position of the main sequence and the giant branches. It must be remembered that the diagram applies directly only to stars which satisfy the mass-luminosity relation. Moreover, we have assumed that the stars are spherical and that their radii are given by the relation for L as for non-rotating stars. Both assumptions are probably incorrect, but in the absence of any observational information regarding the deformation of rapidly rotating stars from spherical shape we find it advisable to use Figure 6 as a guide to determine the *relative* break-up velocities rather than the absolute values. It will be seen that for types O, B, A, and early F the maximum observed velocity is of the order of one-half of the predicted velocity.

The incorrectness of the two assumptions and the neglect of radiation

pressure suggest that the true break-up velocities must be much closer to the observed maximum values and there is all reason to believe that a factor of 0.5 as applied to the values read from the diagram might be close to the truth. The observational results, on the other hand, may be vitiated by darkening at the limb.

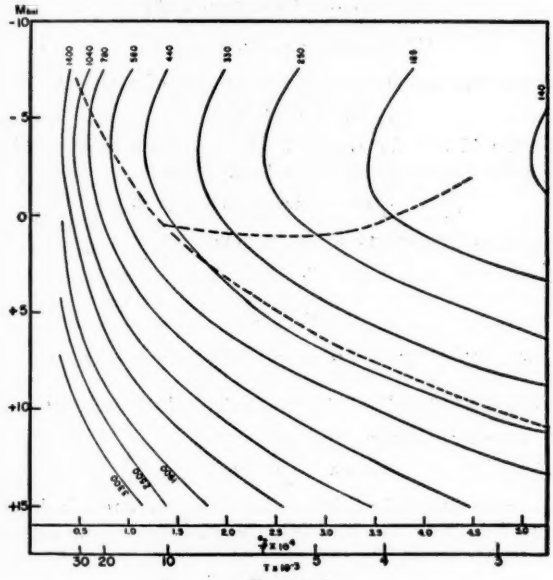


FIGURE 6

We have already seen that the occurrence of bright lines and of shell-absorption in the most rapidly rotating B stars suggests that rotational instability does exist and actually produces observable effects. We have also seen that there is strong reason to believe that the gases of the shell are concentrated in a ring in the equatorial plane of the star.

It is exceedingly probable that we are concerned with the equatorial break-up of a gaseous body which rotates as a solid and which is greatly concentrated towards the center. For such a body, as Poincaré has shown,[36] the equipotential surface is given by

$$[M/\sqrt{(x^2+y^2+z^2)}] + (\omega^2/2)\,(y^2+z^2) = C.$$

When C has an appropriate value the shape of this surface is lenticular, and there is exact balance at the equator of gravity and centrifugal acceleration. This is essentially Roche's model of a rotating mass, and the equation of the critical equipotential surface is

$$1/r + (x^2+y^2)/2a^3 = 3/2a,$$

[36] *Leçons sur les Hypothèses Cosmogoniques*, Paris, 1913; p. 16.
Correction: In line 5, page 259, omit "$= v^2/R$."

where a is the radius of the lenticular edge in the xy plane. It is clear that in this model the ratio of the polar semidiameter to a is

$$b/a = 2/3$$

This could be used to determine corrections for the break-up velocities which we had computed for strictly spherical stars, but it is probably better to use Jeans' result for the critical surface[37]

$$\omega^2/2\pi\rho = M/2\pi\rho a^3 = V/2\pi a^3 = v^2/2\rho\pi a^3 = 0.36075.$$

The fact that in several stars, for example Pleione and γ Cassiopeiae, shells have recently appeared for the first time, may be considered as observational evidence of rotational break-up. The formations are very unstable, as the theory demands. They rapidly change and disintegrate into space.

The question what the motion of the Laplace rings will be after break-up does not seem to have been adequately answered by the theory. Observationally, we have conclusive evidence that the ring rotates slower than the star and that the outer regions of the ring rotate slower than the inner. We have as yet no means to establish observationally the relation

$$v = f(r),$$

because our only criterion of distance, the dilution effect, is not sufficiently precise for this purpose. But we can at least say that the observations in ζ Tauri and other shells are not inconsistent with the hypothesis

$$v = cr^{-1},$$

which would correspond to conservation of angular momentum.

The further development of the shell does not concern us here. We know that in its early stages it is gaseous and has an electron density of $n_e = 10^{11}/cm^3$ or, considering that hydrogen is extremely abundant, a material density

$$\rho = 10^{-12}\ gr/cm^3.$$

Departures from equilibrium conditions are apparent when the shell is first formed. It is therefore reasonable to suppose that cyclical effects will tend to build up L_α radiation density, leading gradually to the phenomena described in an earlier paper.[38]

The beautiful shell of γ Cassiopeiae disintegrated after a total life of only a few years. Another shell, the weakening of whose absorption lines has not previously been announced, is β Monocerotis A. This star had strong and sharp absorption lines of H between wide components of emission, and some weaker lines of Fe II, etc., when it was observed at Yerkes in 1918, 1920, 1924, and 1931. But a spectrogram taken on February 12, 1942, shows that the deep central absorption has almost entirely vanished, although the bright line at Hβ is strong and at Hγ

[37] *Cosmogony and Stellar Dynamics*, Cambridge, 1919; p. 150.

[38] *Struve, Ap. J.*, **95**, 134, 1942.

rather weak. Variations in the bright lines were announced by McLaughlin.[39]

One aspect of the theory of rotational break-up remains very obscure. We know that the formation of shells is not a permanent process, but one which proceeds in spurts. Poincaré's attempt to explain the origin of separate rings in the Laplace theory is not applicable and is not even satisfactory on theoretical grounds, as Nölke has pointed out.

Another apparent difficulty is that not all rapidly rotating stars show shells or bright lines. For example, α Virginis and η Ursae Majoris among the B's give no indication whatever of rotational break-up. The same is true of α Aquilae among the A's. Perhaps this difficulty is related to the preceding one, and the increasing number of discoveries of new bright lines in stars which heretofore had only absorption lines, and of shells in stars which formerly did not possess them, justifies the conclusion that all stars which rotate fast enough may be subject to break-up from time to time.

Cherrington has recently announced that many stars having nebulous absorption lines in their spectra show sharp metallic lines in the visual region. If this observation were correct it would remove the doubts expressed in the preceding paragraph. But Swings and I have failed to confirm Cherrington's observations. In order to clinch the argument we have made long exposures of α Virginis and η Ursae Majoris in the region of the HeI line 3188. Arising from the mestastable level 2^3S it should give rise to a strong line in the shell, provided the excitation is sufficient. There is certainly no strong sharp line at λ 3188. A very weak sharp line may be present in α Virginis, but the whole spectrum is so cut up by the atmospheric ozone bands that the identification is quite uncertain. There are certainly no sharp cores in the Balmer lines.

V. Rotations of the Pleiades and Hyades

I have already referred to the fact that two conspicuous shell-stars—Pleione and 14 Comae Berenices—are members of clusters. Moreover, I have called attention to the frequent occurrence of Be stars in the Pleiades and in the double cluster of Perseus. If the phenomena of bright lines and shell absorption are connected with rotational break-up of the stars we should expect to find exceptionally many stars of rapid rotation in these clusters.

With regard to the Pleiades I have for many years been aware of the fact that the brighter members nearly all have broad and diffuse absorption lines. The lines of HeI and MgII in the B stars show the same dish-shaped contours which we have been consistently led to interpret as a result of rapid rotation. The maximum velocities derived in the usual way are large, but are not excessive. Incidentally, in several stars the lines were so broad and shallow that they were not measured

[39] *Pub. Michigan U. Obs.*, **4**, 183, 1932.

by Miss Westgate and are not included in her lists of $v_0 \sin i$. Some additional evidence for the brighter Pleiades was published by Payne and Maulbetsch.[40] Their conclusions are as follows:

(1) "The change of line width with wave-length is different for hydrogen and helium, an observation unfavorable to a rotational interpretation.

(2) "The widths of the absorption lines are uncorrelated, for the Pleiades, with the intensity of the emission lines.

(3) "The change of line width with wave-length for the hydrogen lines is such that the inferred natural widths of these lines is less than zero, unless the greater part of the slope is of non-rotational origin; the same holds even more strongly for helium.

(4) "If the slopes of the absorption lines of hydrogen in the Pleiades were rotationally interpreted, we should conclude that all the brighter stars in the cluster have the same equatorial velocity at the limb—a most improbable result."

In keeping with these conclusions the authors find that "the widths of absorption lines in bright-line stars are difficult to interpret in terms of axial rotation."

Swings and I have shown[41] that the observed velocity of rotation of 2000 km/sec derived from the slopes of the H lines is simply a result of Stark effect. The H lines are not (and never have been) considered as satisfactory indicators of rotation. The He lines are also, in part, influenced by Star effect, and this, according to Shajn, accounts for their behavior in the Pleiades. Nevertheless, in stars with very broad lines the He lines are broadened almost wholly by rotation.

Point (2) is probably not serious. The bright-line stars in the Pleiades actually do have very large rotations:

Electra	200 km/sec
Merope	300 "
Alcyone	150 "
Pleione	300 "

These four stars are listed by Merrill and Burwell as of type Be. Payne and Maulbetsch attribute bright-line character also to Maya, Taygeta, and Celaeno. Since they are not listed by Merrill and Burwell the Be character is somewhat doubtful, but in any case, the corresponding rotations are 10, 75, and 150 km/sec. The only star of small rotation is Maya, and it may well be oriented in such a way that i is close to 0°.

Objection (4) is doubtless the most serious of all. Although my results do not indicate that all the brighter Pleiades have identical rotations, they do, very definitely, show that the rotations are, on the average, much larger than for normal B stars in the galaxy. In 1941 Dr. John Titus at Yerkes independently concluded that not only the brighter members of the cluster, but even some of the fainter members show surprisingly diffuse and shallow lines.

[40] *Harvard Circ.*, No. 364, 1931. Mrs. Payne Gaposchkin has read this section and has permitted me to say that she agrees with its conclusions.

[41] *Ap. J.*, **75**, 180, 1932.

With the additional information which has been accumulated in the intervening ten years we can no longer ignore the diffuse lines of the Pleiades. Our entire stock of knowledge favors the rotational interpretation. The great frequency of Be stars and the recent origin of a shell around Pleione—having previously been related to rapid rotation—tend to strengthen our conclusion. In my opinion the course is perfectly clear. We must either abandon everything that we have learned about rotation and attribute the diffuse lines to the action of a process of line broadening not now known in physics, or we must accept the "improbable" conclusion that rapidly rotating stars are more frequent in the Pleiades than in the galaxy at large. I hope I have made it abundantly clear in the preceding pages that the second alternative is the only one that we can accept.

In order to provide additional material I have secured spectrograms of 70 members of the Pleiades, including all stars belonging to the cluster which are not fainter than visual magnitude 9.0. The dispersion of the spectrograph (attached to the 82-inch reflector of the McDonald Observatory) is 40 A/mm at λ 3933 and 75 A/mm at λ4500. This dispersion is considerably smaller than that previously used in studies of stellar rotation. Nevertheless, a comparison with plates of higher dispersion for selected stars indicated that rotations of about 50 km/sec produce noticeable broadening and at 75 km/sec the broadening is easily detected. Rotations of 25 km/sec or less cannot be detected with certainty. The rotations were estimated after a comparison of the McDonald plates with those used by Miss Westgate. The estimates were made twice, and the agreement was excellent.[42] The values given are definite indications of varying degrees of rotation. But a calibration with Miss Westgate's measures of line widths suggests that, on the average, my rotations of zero should be increased to 25 and my rotations

TABLE 5

ROTATIONAL VELOCITIES OF PLEIADES

Trumpler's No.	Photogr. mag.	Sp. (Morgan)	Rotation $v_0 \sin i$ km/sec	Trumpler's No.	Photogr. mag.	Sp. (Morgan)	Rotation $v_0 \sin i$ km/sec
			Types B6 to B9				
139	5.3	B5	150	414	2.8	B7	150
148	3.6	B6	200	506	5.4	B8	250
166	5.7	B5	100	594	3.6	B8	300
170	4.2	B7	75	602	5.0	B8p	300
231	3.8	B7	10	622	6.5	B9	0
240	5.7	B8	75	671	6.0	B8	100
247	6.3	B9	150	S149	6.0	B8	50
286	4.2	B6	300	S142	6.9	B9	100
354	6.7	B9	150	S194	7.1	B9	0

[42] An independent set of estimates from a larger amount of material was given in *Ap. J.*, **100**, 360, 1944.

Trumpler's No.	Photogr. mag.	Sp. (Morgan)	Rotation $v_0 \sin i$ km/sec	Trumpler's No.	Photogr. mag.	Sp. (Morgan)	Rotation $v_0 \sin i$ km/sec
			Types A0 to A5				
74	8.2	A5	0	688	7.5	A2	25
195	8.2	A4	100	697	6.8	A0	0
208	8.9	A2	25	791	7.0	A1	50
215	7.3	A0	0	848	9.1	A5	100
235	8.0	A4	50	234	6.9	A0	75
281b	8.7	A3	100	S177	6.3	A0	0
295	7.4	A2	0	S 25a	6.5	A1	0
311	8.5	A2	50	S 23	6.7	A0	100
365	8.6	A2	100	S 25	7.1	A0	0
395	6.3	A0	75	S 26	7.4	A0	25
397	6.9	A1	100	47	7.7	A2	50
399	7.8	A3	100	S 76	7.8	A3	50
402	7.2	A0	0	S137	7.9	A0	50
410	7.9	A4	75	S165	7.9	A0	50
413	6.8	A0	0	S 78	8.1	A0	100
493	8.5	A3	150	S 84	8.3	A0	75
518	7.0	A2	25	S115	8.5	A2	0
613	7.6	A2	200	S185	8.5	A0	0
629	8.1	A5	50				
			Types A6 to F8				
R 11	10.1	F8	0	331	9.8	F8	0
50	8.3	F0	25	359b	9.0	F0	25
51	8.4	A7	0	390	8.4	F0	0
121	8.4	F0	150	551	8.6	F0	50
149	9.3	F5	0	607	8.3	A8	150
162	8.8	A7	25	651	9.5	F8	75
180	9.5	F5	0	670	8.3	A8	0
HD23464	9.4	G0	0				

TABLE 6

MEAN ROTATIONAL VELOCITIES OF PLEIADES

Type	No.	Mean $v_0 \sin i$
B6 to B9	18	130 km/sec
A0 to A5	37	53
A6 to F8	15	33

of 200 and greater should be decreased by about 50 in order to reduce my values to her system. It is, I think, preferable not to make this reduction, but to remember that the two systems are not entirely alike. The results are shown [42a] in Table 5. For the bright B stars the rotations were confirmed by means of Yerkes plates of higher dispersion. The means are shown in Table 6. The mean rotational velocities from Miss Westgate's work are in Table 7.

TABLE 7

MEAN ROTATIONAL VELOCITY IN THE GALAXY

Spectrum	No.	Mean $v_0 \sin i$
B	275	73 km/sec
A	413	87
F	112	23

[42a] The estimated velocities published by Smith and Struve (*Ap. J.*, **100**, 360, 1944) represent independent values made from a larger amount of material, which includes that used here. The differences between the two sets of values are due to the unavoidable accidental errors in making these estimates.

The comparison is not reliable because of the systematic difference between the two series. Neverthless, the excess of rotations in the Pleiades of type B is very striking.

Figures 7, 8, 9 show the distribution of the velocities in the sky. There is a tendency for the largest rotations to occur near the center of the cluster. Even among the A's the largest rotations are more frequent near the center of the cluster than at the outskirts. But this effect is not particularly striking.

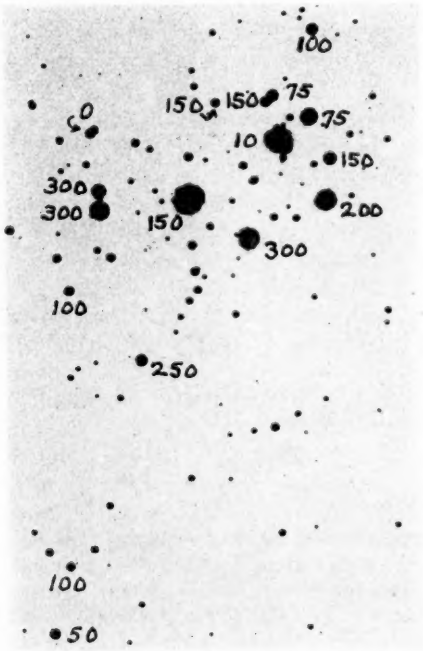


FIGURE 7

Types B5 to B9 inclusive.

What is striking, is that only the B's have a large excess of rotation. The A's have some large rotations, but are, on the average, perhaps normal, while the F's have only two large rotations, one being F0, and the other F8. This can hardly be regarded as abnormal. The general tendency for the early types to have the largest rotations, already found in the galaxy at large, is preserved. But the B's are quite abnormal, while the A's are almost normal.

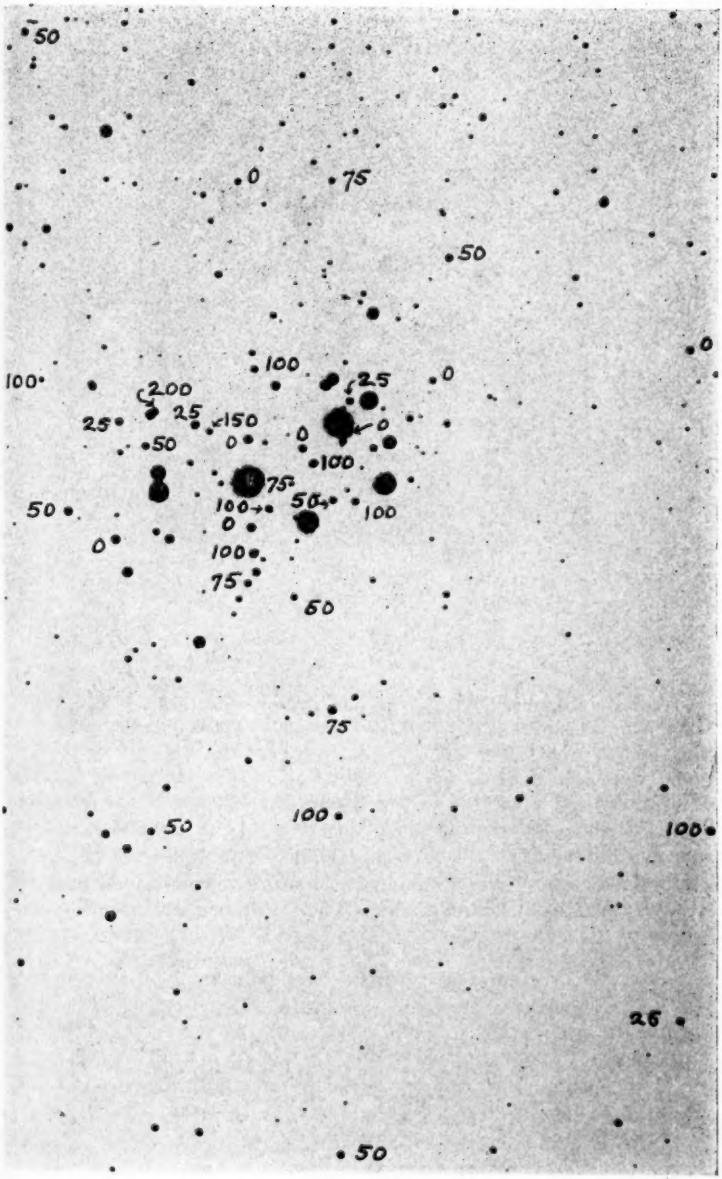


FIGURE 8
Types A0 to A5 inclusive.

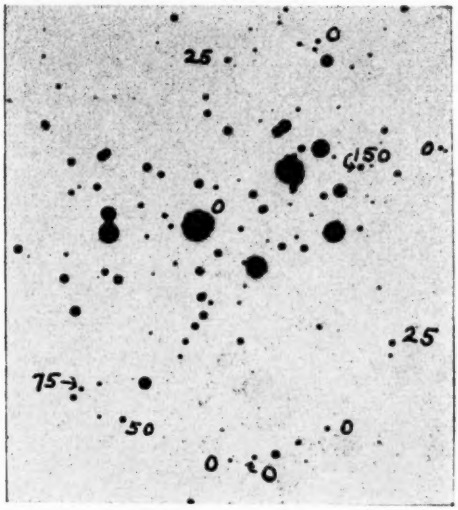


FIGURE 9
Types A6-F-G

TABLE 8

ROTATIONAL VELOCITIES OF THE PLEIADES

	Inner Region		Outer Region	
Spectrum	No.	$v_0 \sin i$	No.	$v_0 \sin i$
B6 to B9	7	173 km/sec	11	114 km/sec
A0 to A5	15	69	22	42
A6 to F8	2	75	13	27

If we divide the material in two groups, those stars which lie within 30′ of Alcyone, and those outside this limit, we obtain the results in Table 8. The effect of distance is undoubtedly present.

In order to secure comparable material for another cluster I have observed 50 members of the Hyades. The results are in Table 9.

TABLE 9

ROTATIONAL VELOCITIES OF HYADES

Smart No.	Spectrum	$v_0 \sin i$ km/sec	Smart No.	Spectrum	$v_0 \sin i$ km/sec
		Types A0 to A5			
7	A5	25	30	A5	0
12	A3	0	31	A5	0
15	A5	0	34	A5	75
17	A3	50	36	A3	0
19	A2	0	38	A3	50
21	A5	250	39	A3	25
22	A5	150	42	A2	0
23	A5	25	67	A0	0
28	A5	25	72	A5	100

Smart No.	Spectrum	$v_0 \sin i$ km/sec	Smart No.	Spectrum	$v_0 \sin i$ km/sec
		Type F0			
1	F0	25	32	F0	50
2	F0	100	33	F0	75
3	F0	0	35	F0	25
5	F0	0	37	F0	0
10	F0	0	40	F0	100
16	F0	50	45	F0	0
18	F0	150	49	F0	75
24	F0	25	50	F0	50
27	F0	50	53	F0	0
29	F0	100	71	F0	25
	Types F2 and Later			Bright K Giants	
6	F5	25	8	K0	0
9	G0	0	13	K0	0
11	F2	0	25	K0	0
14	F2	0	26	K0	0
20	F8	0			
43	F2	25			
46	F8	0			
63	F2	0			

The mean values of $v_0 \sin i$ are shown in Table 10.

TABLE 10

MEAN ROTATIONAL VELOCITIES OF HYADES

Type	No.	Mean $v_0 \sin i$
A0 to A5	18	42 km/sec
A6 to F0	20	45
F1 to G	8	6
K0 Giants	4	0

VI. THE PROBLEMS OF PLEIONE AND MAYA

In Table 5 Pleione is entered with a rotational velocity of 300 km/sec. This is based upon the widths of the absorption lines of HeI and MgII prior to the appearance of a shell-spectrum in 1938. The spectrum of the latter has been discussed elsewhere.[43] The star had emission lines of H from 1888, when it was first observed at Harvard, until 1903 when double bright lines were seen by Jung. In 1905 Frost could not detect any bright lines and they remained invisible until 1938. In October of that year McLaughlin and Mohler announced the reappearance of emission lines of H. McLaughlin also found narrow absorption cores of H, as far as Hη, and a large number of weak, narrow lines of FeII, TiII, ScII, CrII, NiII, and perhaps VII. Since that time the spectrum of the shell has grown in strength until the equivalent widths have increased several times. There has been no large change in ionization, but a slight lowering is indicated by the increase of FeI, CaI, and CaII. The dilution is very conspicuous, but MgII 4481 is present in the lower strata of the shell. It is broader than the lines of FeII and TiII, but is not as broad, nor as shallow, as it was prior to 1938. The same is true of SiII.

At the present time (1942) the spectrum of the shell is characterized

[43] Struve and Swings, *Ap. J.*, **93**, 446, 1941; Kiess, Krogdahl, Bidelman, and Hall, *Pub. Am. Astr. Soc.*, **10**, 1942.

by the extreme weakness of the many lines of MnII in the ultraviolet region. The contours of the lines are not normal. In the ordinary photographic region the stronger metallic lines (of FeII and TiII) are sharper than the weaker lines. In addition, the lines of FeII are systematically sharper than the lines of TiII. The effect produces an appearance which suggests larger turbulence or larger rotation for the fainter lines than for the stronger lines. In ordinary stellar spectra we normally expect the faint lines to be sharper than the strong lines. The spectrum does not change rapidly. The bright lines are relatively weak: Hα is fairly conspicuous, but Hβ shows only a weak emission component on the violet side of the sharp absorption core, and possibly a very faint trace of a bright component on the red side. The velocity of the shell is roughly the same as that of the star prior to its outburst. There has been no conspicuous change in total light, although Calder believes that it has become fainter by a sixth of a magnitude. E. G. Williams found an increase in color index.

I have already indicated that the formation of a shell in Pleione can best be explained as the result of equatorial break-up.

Among the 18 B stars of Table 5 are three for which the rotational velocity is negligibly small. These three are

No.	Sp.	$v_0 \sin i$
231	B7	10
622	B9	0
S194	B9	0

Two are of type B9 and have spectra so similar to those of the A stars, that they more properly belong to that group. If we arrange the B stars according to $v_0 \sin i$ we obtain the following frequencies:

TABLE 11

$v_0 \sin i$	No. (All B Stars)	No. (Omitting B9)
0- 49	3	1
50- 99	3	3
100-149	3	2
150-199	4	2
200-249	1	1
250-300	4	4

Although the distribution is based upon a small amount of material it is entirely different from that found by Miss Westgate for the galaxy at large. There is here a tendency to show the greatest frequency for the largest velocity and the lowest frequency for small values of $v_0 \sin i$. This suggests that the true dispersion in v_0 is much less than in the galaxy, and that perhaps a large part of the dispersion in $v_0 \sin i$ results from random distribution of i.

The one star earlier than B9 which has no appreciable rotation[44] is

[44] The adopted rotational velocity of 10 km/sec is Miss Westgate's value. I am not able to detect rotational broadening on the Texas spectrograms, but suspect a slight broadening of the He lines, possibly due to Stark effect, on the best Yerkes plates.

Maya (No. 231 in Table 5). It is bright, and by all criteria should resemble the rest of the bright B stars. The possibility arises that we have here a rapidly rotating B star whose inclination is near zero. I must emphasize that this cannot be proved. The only supporting evidence which we can adduce is that the spectrum is not that of a typical shell. The H lines show no cores, the lines of SiII and MgII are present with considerable intensity. Dilution is not ruled out, as we shall see, but if it is present it must be much weaker than in Pleione.

Our interest in Maya is enhanced when we recall that its spectrum was found to be abnormal on grounds altogether different from those which we have just discussed.[45] When we arrange the best main-sequence stars in the galaxy in a classification scheme according to the usual line criteria we find that Maya cannot be uniquely placed. The lines of HeI 4472 and 4380 are relatively weak, but so is also MgII 4481. From the He lines we should infer a relatively lower temperature than from the MgII line. At the same time the lines of FeII 4549 and 4233 are quite strong and favor an even lower temperature than the one inferred from HeI. When we examine the spectrum in the ultraviolet region we are struck by the large number of sharp metallic lines. Especially strong are the lines of MnII, while TiII and FeII are relatively weaker, and NiII and CrII are still weaker. In this respect Maya resembles somewhat ϕ Herculis, in which the metallic lines are stronger, and γ Corvi, in which they are similar. But in ϕ Herculis the lines of NiII, CrII, etc., are relatively stronger than in Maya. Since the second ionization potential of Mn is 15.7 volts, while that of Ni is 18.2 volts, we should have expected NiII to be relatively strong in Maya, as it is in the shell of Pleione and in the giant 4 Lacertae. But there is evidence that NiII is abnormally strong in some shells (48 Librae), and this may account for its strength in Pleione. On the other hand, we have referred to the weakness of MnII in Pleione. This is not characteristic of all shells, because these lines are strong in 17 Leporis and 14 Comae.

The strength of MnII in Maya is probably abnormal only in the sense that it tends to place it in a later spectral sub-division than is consistent with HeI and MgII. It is difficult to estimate the amount. If we assume that the HeI lines would place the star at B7, we should be inclined to place it at B4 or B5 from MgII and at B8 or slightly later from FeII and MnII.

Kuiper's temperature scale[46] then shows that the spectrum of Maya may be regarded as a composite, corresponding to an extreme range in temperature from 15,500° to 12,300°. It is precisely such a range that we should expect to observe in a rapidly rotating star for which i is small. According to von Zeipel[47] the surface brightness of a rotating

[45] *Ap. J.*, **78**, 81, 1933.
[46] *Ap. J.*, **88**, 446, 1938.
[47] *M. N.*, **84**, 665, 1924.

star is

$$H \propto g$$

and, accordingly, the temperature at the poles is greater than at the equator. Milne[48] has computed that for Eddington's typical giant star of density 0.002 a rotation with a period of seven days would produce a difference of about 10 per cent in the temperatures at the pole and at the equator. This star has a radius of 7×10^6 km and an effective temperature of 6500°, a mean molecular weight of 2.8 and a mass of $1.5\odot$. The rotation amounts to 73 km/sec, and the ratio of centrifugal force to gravity is about 0.19. If Maya rotates as rapidly as the other bright members of the Pleiades, v_0 must be several times greater than the ratio of centrifugal force to gravity may be close to one. In that case the difference in temperature between pole and equator could easily be 20 or 25 per cent, as we have observed.

There is, however, one serious objection to the proposed explanation. The metallic lines would all come from the equatorial regions, and the He I lines from the polar regions. Now, the best spectrograms I have show perfectly sharp and narrow lines of Mn II, Fe II, etc. It would be almost too much of a coincidence were i so close to zero that lines produced only in the equatorial regions should be perfectly sharp. There is the additional difficulty that Mg II 4481 is relatively too weak for the observed intensities of Mn II, Fe II, etc. I am, therefore, inclined to think that we must, after all, attribute the metallic lines to some sort of shell, in which the temperature is lowered by rotation, and dilution produces a small amount of weakening in Mg II 4481. Conservation of angular momentum would then reduce the rotation of the shell and render its lines narrow. It is also possible that the rotation is small and that the spectrum is peculiar.

VII. The Origin of Stellar Rotation

The theories of the origin of stellar rotation may be divided into two groups, those which attribute the rotations to internal forces and those which attribute them to external forces.

In favor of the first group is the sudden "jump" in the average value of $v_0 \sin i$, as we pass from the early to the late subdivisions of class F. Gamow[49] also calls attention to the fact that this is precisely the point in the main sequence where the branch of the giants starts. However, there are two serious objections: (1) the existence of a large dispersion in $v_0 \sin i$ among stars of identical physical characteristics, and (2) the systematic differences in $v_0 \sin i$ between the Pleiades and stars in the galaxy at large. It would appear that it is not possible to isolate a star from its surroundings and to have it evolve by contraction until the rotation is near the critical value.

The observational results for the Pleiades suggest, on the contrary,

[48] *M. N.*, **83**, 139, 1923.

[49] Unpublished.

that the environment determines the origin of $v_0 \sin i$. Here, again, two possible mechanisms suggest themselves: (a) the building up of rapid rotation from close encounters of stars, and (b) the building up of $v_0 \sin i$ from the (past) infall of nebular or interstellar matter.

Let us consider first hypothesis (a). Bok estimates the average density of the Pleiades as $2.2\odot/pc^3$.[50] The star density in the neighborhood of the sun is $0.04\odot/pc^3$. The increase by a factor of 55 is probably not sufficient to cause sufficient numbers of collisions between the stars of the cluster. N. S. Orlov[51] finds from an application of the virial theorem that the density at the center of the cluster is about $16.3\odot/pc^3$, or about 400 times the density in the sun's neighborhood. But the random motions of the cluster members are only 0.5 km/sec. Hence collisions will be exceedingly rare. Moreover, the distribution of rotations built up as a result of transfer of orbital angular momentum into rotational angular momentum must have a very large dispersion. In general, an encounter which has produced a certain amount of rotation may be followed either by a second favorable encounter, or by an unfavorable encounter which tends to cancel the rotation built up by the first encounter. The probability of a succession of n favorable encounters is $(0.5)^n$, and the probability of a cancellation of the rotations is considerably greater. We should thus have more slow rotations than fast ones, while in reality the opposite is true.

Hypothesis (b) is rendered more probable by the fact that the Pleiades, in opposition to the Hyades, are enveloped in a dense nebulosity of the reflection kind. The fact that the nebula exists, and that it has neither fallen into the stars, nor been dispersed by radiation pressure into space is an indication that it consist of dust particles whose radii are not smaller than[52]

$$a = 10^{-5} \text{ cm}.$$

Orlov's application of the virial theorem and Hertzsprung's confirmation of the relative motions of the Pleiades, which has been extended by Titus[53] who finds $v = 0.59$ km/sec, show that the total mass of the cluster is about $260\odot$. The known stellar members account for $200\odot$ according to Titus. Hence the mass of the nebula must be of the order of $60\odot$, or since the cluster has a radius of about 3 pc, the density of the nebula is about $0.5\odot/pc^3$ or 4×10^{-23} gr/cm^3. If we designate the density of the particles by ρ and their number per cubic centimeter by N we have

$$(4/3)\,\pi a^3 \rho N = 4 \times 10^{-23}$$

or, with $a = 10^{-5}$ cm and $\rho = 1$,

$$N = 10^{-8}/\text{cm}^3.$$

[50] *Harvard Circ.*, No. 384, 31, 1934.
[51] *Leningrad Univ. Scient. Papers*, No. 22, 1938.
[52] Struve, *Ann. d'Ap.*, **1**, 143, 1938.
[53] *A. J.*, **47**, 25, 1938.

The mean free path of these particles is

$$\lambda = 1/\sqrt{2}\,\pi\,N\,a^2 \approx 10^{17}\text{ cm} = 0.03\text{ pc.}$$

Now, the average distances between the members of the Pleiades are of the order of one parsec. Hence, the number of collisions over this distance is roughly 30. This is not nearly sufficient to permit us to apply without reservation the formula of Hoyle and Lyttleton for the accretion of mass by a star which passes through a nebula. On the other hand, the relative velocities of star and nebula must be small—of the order of 0.5 km/sec. The formula of Hoyle and Lyttleton[54] is

$$dM/dt = 18\,\gamma^2\,M^2\,\rho/v^3;$$

γ is the constant of gravitation, M is the mass of the star, ρ the density of the cloud and v the relative velocity of the cloud with respect to the star. If collisions are infrequent, only a fraction ψ of the maximum possible will fall into the star. But since dM/dt is proportional to M^2 and inversely proportional to v^2 we can make ψ quite small and still obtain an appreciable increase in mass. We are thinking here of clouds of nebulous material which move within the gravitational field of the entire cluster and from time to time "collide" with a star. The term M^2 shows that the B stars must be particularly sensitive to this mechanism. In order that we may apply the formula of Hoyle and Lyttleton it is necessary that the collisions be inelastic, so that a part of the angular momenta of the two particles be cancelled. But G. H. Darwin[55] has shown that an appreciable fraction of two heavy meteors will become volatilized in the collision, and that the gas thus created will produce "what is virtually a violent explosive introduced between the two stones."

In our case the energy generated in a collision of two particles meeting head-on should be more than is required to volatilize them. In all probability the particles will be transformed into gas. This gas will then be subjected to the attraction of the star and to its radiation pressure. A fraction of the material may fall into the star.

But mass accretion will not of itself cause rotation. This can only happen if the motions of the cluster are not purely random ones, but if there is from the beginning some angular momentum in the cluster; in other words, the entire cluster must rotate. There is as yet no evidence that such a rotation exists. Only a relatively insignificant amount of "organization" is required in order to enable the nebular material to impart the required amount of angular momentum to the star. The astrophysical picture of the proposed mechanism is closely related to that considered by Russell[56] several years ago. The particles will become vaporized long before they reach the reversing layer of the star.

[54] *M. N.*, **101**, 227, 1941.
[55] *Phil. Trans. R.S.*, **180**, A, 3, 1889.
[56] *Ap. J.*, **69**, 49, 1929.

But, as Russell has pointed out, they may become ionized to such an extent that they will not be driven away by radiation pressure, but will continue to fall into the star. I believe that this aspect raises a rather important and as yet obscure question. The individual atoms of what was once a meteor will, if conditions are suitable, fall into the star and collide with atoms of the uppermost layers of the chromosphere or even corona. Hence whatever angular momentum they can impart will be delivered to these upper strata and then be very slowly transmitted to the rest of the star.

This, however, raises the uncomfortable question why we never observe appreciable rotations in the supergiants. Figure 6 shows that their break-up velocities are not much lower than those of main-sequence stars. Their masses are large and Hoyle and Lyttleton's formula predicts a large value of dM/dt. If the meteor could pass through the atmosphere of a supergiant as a solid body, it would meet so little resistance that it would not appreciably disturb it. But Russell's work disposes of this idea. Turbulence is probably active in all supergiants and it will tend to distend the atmosphere in the manner suggested by McCrea. But even if the reversing layer of such a star should not rotate as a solid body, but follow the relation $v \propto r^{-1}$, the height r can hardly be great enough to mask entirely the rapid rotation of the star below. We must conclude that supergiants do not rotate rapidly.

In one sense, we need not be worried: There are no super-giants in the Pleiades. Those in the Hyades have zero rotation, but we have already seen that the rotations in this cluster do not differ from those in the galaxy at large. Perhaps we must conclude that supergiants originate only in such regions of space where the primordial medium does not possess organized motion.

VIII. Conclusions

The work which I have described rests upon observations of only two clusters. We have, in addition, the evidence of Trumpler for the double cluster of Perseus. There are many Be stars and the entire group of faint B stars is characterized by abnormally faint lines of He. Higher dispersion may show that here, too, the rotations are large. But h and χ Persei contain a number of B-type as well as late-type supergiants, and, as far as can be judged, these show no rotations. The problem of the giants and supergiants remains unsolved.

In conclusion we can say that we have given convincing evidence of the existence of large rotations in early-type stars. We have shown that in the Pleiades the rotations of the B stars are excessively large, on the average, but in all stars equatorial break-up sets an upper limit to v_0. We have made it appear probable that the formation of a shell represents the process of rotational break-up, and we are thus probably witnessing by means of our spectrographs the actual formation of the rings of Laplace:

"L'atmosphère . . . ne peut pas s'étendre indéfiniment; sa limite est le point où la force centrifuge due à son mouvement de rotation balance la pesanteur; or, à mesure que le refroidissement resserre l' atmosphère . . . le mouvement de rotation augmente; . . La force centrifuge due à ce mouvement devenant ainsi plus grande, le point où la pesanteur lui est égale est plus près de ce centre. . . l'atmosphère . . . a dû . . . abandonner les molécules situées à cette limite et aux limites successives produites par l'accroissement de la rotation. . . Ces molécules abandonnées ont continué de circuler autour de cet astre, puisque leur force centrifuge était balancée par leur pesanteur."[57] Perhaps if Laplace could have known what we now know about the spectra of shells, he would not have preceded his famous hypothesis with the words ". . . une hypothèse . . . que je présente avec la défiance que doit inspirer tout ce qui n'est point un résultat de l'observation ou du calcul."[58] But in that case he would hardly have suggested that the gaseous rings would condense into planets.

[57] *Oevres Complètes*, t.6, Paris, 1884, p. 501.
[58] *Ibid.*, p. 477.

Frederick Slocum
1873-1944

By **OLIVER JUSTIN LEE**

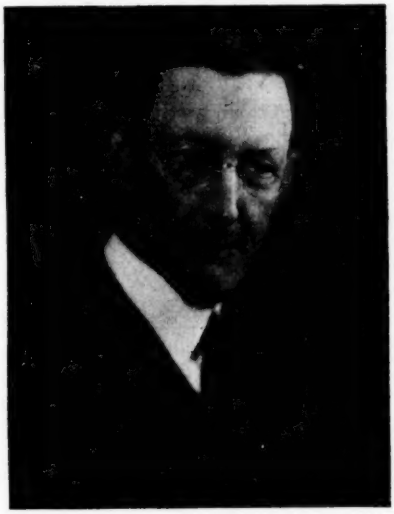
In five years of almost daily association with Slocum at Yerkes and occasional contacts with him since then, I never heard him say an unkind thing to or about any person. Once, Dr. Carl Stearns tells me, he almost did. He was showing some visitors about in the Van Vleck Observatory when one of them laid hands on the pier which supports a transit instrument and tried to shake it, remarking as he did so, "Professor, how often do you have to adjust this instrument?" The director, who had just been helping a student to adjust it, remarked dryly, "Every time we have visitors."

Frederick Slocum was born in Fairhaven, Massachusetts, on February 6, 1873, the son of Captain Frederick and Lydia Ann (Jones) Slocum. He attended Brown University and received the B.A. degree with honors in 1895. Later Brown gave him three more degrees, A.M. 1896, Ph. D. 1898, and Sc. D. 1938.

He earned the money for his college course by tutoring in mathematics and by fishing for flounder off Cuttyhunk Island and marketing his catch on the mainland. He still took time to play on the Brown baseball team and to captain a company of R.O.T.C. cadets.

He was an instructor in mathematics from 1895 to 1900. Part of this time he lived in the home of Winslow Upton, Professor of Astronomy. This association changed the course of his career and in 1900

he became assistant professor of Astronomy. With two scientific excursions away from Brown he remained in this position until 1909. In 1907 he spent the summer as volunteer research assistant with Fox at Yerkes, and the year 1908-9 in the same capacity at the Royal Astrophysical Observatory in Potsdam, Germany. Upon his return he became instructor in astrophysics at Yerkes, succeeding Fox who in that year became director of Dearborn Observatory. He was made an assistant professor in 1911, remaining until 1914 when he resigned to go to Middletown (Conn.) Wesleyan as professor of Astronomy and to plan, erect, and direct the new Van Vleck Observatory. With some brief absences to teach navigation during the first World War and for scientific assignments, he remained as director until his death.



Photograph by Bachrach

FREDERICK SLOCUM

He was a member of the National Research Council 1934-37, member of the American Academy, American Astronomical Society, Astronomische Gesellschaft, the Société Astronomique de France, and a Fellow of the Royal Astronomical Society of London. He held the office of Vice-President, Section D, in the American Association of the Advancement of Science in 1934, and the Vice-Presidency of the American Astronomical Society in 1935-37.

During his five years at Yerkes he published a number of papers on solar phenomena and stellar parallaxes. The principal program of the 20-inch Van Vleck refractor has been the determination of stellar

parallaxes. He shared in the observing, but generously left the measurement, reduction, and publication to his colleague, Dr. Stearns.

Including a list published in 1942, Stearns has done 185 parallaxes, a very valuable contribution in this difficult and important field.

Slocum's first paper, in the *Astrophysical Journal* of May, 1897, was a "Note on the Distortion due to the Lens in a Projection Drawing." From 1911 until 1928, about one paper a year by him appeared, on a wide variety of subjects. Several of these were concerned with troublesome questions in astrometry such as the possible errors due to atmospheric dispersion, differential refraction, and guiding error.

The path of totality of the solar eclipse of January 24, 1925, passed directly over the Van Vleck Observatory. Slocum and his associates secured a number of photographs of the corona with and without color filters. On that occasion the observatory and its staff were hosts to a number of visiting eclipse parties. Mrs. Slocum and he went to Aal, Hallingdal, in Norway to observe the eclipse on June 29, 1927. They had an interesting summer, but were clouded out on eclipse day.

At Wesleyan he was chairman of the committee on graduate studies and active in the local chapters of Sigma Xi and Phi Beta Kappa. In his earlier years there, he was active in campus theatrical productions, and throughout his residence in Middletown, in the Conversation Club. The latter is composed of town and gown men and meets once a month for dinner, a paper, and discussion. While at Yerkes he was an active member of a local Congregational (union) Church, in which he served as treasurer for several years.

Frequently on cold winter days Slocum and I would don our heavy fur-lined observing clothes and have a short round of golf in the snow, using red golf balls. It was poor golf but grand exercise.

Slocum's marriage to Carrie E. Tripp of New Bedford, on June 29, 1899, began a singularly happy companionship, which was terminated by the death of Mrs. Slocum in May, 1942. Her gentle, devoted husband followed her on December 4, 1944. The writer was often a guest in their beautifully appointed home, where cheerful, laughing Carrie was queen, and "Fred-Eric" (Mrs. Slocum's homey name for her husband) was happy prime-minister.

Slocum's father was a whaling captain, who married his second wife in October and the following May started with her on a four-year voyage, much of which was spent in trading in the region of the Macassar Straits and the China Sea. On the way Mrs. Slocum gave birth to twins, a boy and a girl, at Fayal, Azores Islands. Many years later when Fred was at Yerkes, this brother, Captain Abram J. Slocum, was lost at sea with his schooner and all hands, off the coast of the Carolinas-Virginia, northward bound. No report of the disaster ever came. Fred had made several trips with this brother during vacations. From childhood the boys were taught the ways of boats and the sea.

The father had built a home on Cuttyhunk in 1871-2, and the family

lived on the island for many years, except during the winter months, when they returned to New Bedford. Fred was an expert surf-casting fisherman for striped bass and for a time held a record by catching 13 bass of an average weight 38¾ pounds in one day. The heaviest weighed 62 pounds, the smallest 20.

Shortly after marriage he acquired the Vanora, a catboat, which they sailed until they came to Yerkes. After World War I, they bought the Vanora II and used it until 1939. In 1923 he was navigator on William H. Hand's schooner, Black Hawk, in the Bermuda Races.

Slocum was not much of a talker. Only rarely was it possible to get him to speak of the drama and adventure of the sea, such as, for example, shipwrecks around Cuttyhunk, when the colony of islanders were thrown into immediate action to recover what they could, under the rules of Marine Law covering the Rights of Salvage.

We shall miss Slocum, with his tall, straight, streamt-lined figure; his strong, almost ascetic face; his ready, friendly smile; his solid scholarship and well considered counsel.

His closest surviving relative is a brother, Mr. Edward M. Slocum, of New Bedford, Massachusetts, to whom the writer is indebted for much of the personal detail used in this article.

DEARBORN OBSERVATORY, EVANSTON, ILLINOIS, APRIL 23, 1945.

Mars at Opposition Near Perihelion

By R. B. WEITZEL

Mars makes a synodic revolution, or average circuit of its elliptic orbit, in 779.936 days. The brightness of the planet depends upon its position in the orbit and its nearness to Earth. During a synodic revolution, Mars is nearest Earth within nine days of solar opposition.

When Mars is at opposition to the sun near the planetary perihelion, it is at least distance from Earth, 35 million miles, and its brightness may reach a maximum of —2.8, but that stellar magnitude for the planet is of very rare occurrence. When Mars is at opposition near aphelion, its distance from Earth is 61 million miles, and its brightness is —1.0, the minimum for an opposition. When Mars is near conjunction with the sun, it is at maximum distance from Earth, 248 million miles, seven times its distance at favorable opposition, and it is faintest with a +2.0 magnitude.

Mars is seventy-five times brighter at favorable opposition near perihelion than at conjunction, fifteen times brighter at opposition near aphelion than at conjunction, and five times brighter at favorable opposition near perihelion than at opposition near aphelion. Thus, Mars is least bright at conjunction, noticeably bright at opposition near aphelion, and very bright at opposition near perihelion.

A table of Mars at opposition near perihelion is supplied. The

columns give, in order, date of opposition, Julian day number, place of sun, mean longitude of Mars minus its perihelion value, and difference in time between opposition and mean perihelion.

Mars	Opp.	Hr.	G.C.T.	☉	ML-π	Diff. d	Mean π
30	VII 22,	10	1732218.42	116°40	357°0	+5.63	1732224.05
109	VII 26,	13	1761077.54	121.22	359.8	+0.33	1761077.87
188	VII 30,	15	1789936.63	126.01	2.7	−4.94	1789931.69
205	years		74870.66				
393	VII 25,	7	1864807.29	122.23	356.4	+6.92	1864814.21
472	VII 29,	9	1893666.38	127.02	359.2	+1.65	1893668.03
551	VIII 3,	8	1922525.33	131.69	1.8	−3.48	1922521.85
284	years		103730.09				
835	VIII 2,	10	2026255.42	132.96	358.6	+2.77	2026258.19
914	VIII 6,	11	2055114.46	137.68	1.3	−2.45	2055112.01
993	VIII 10,	9	2083973.37	142.38	4.0	−7.54	2083965.83
205	years		74870.75				
1198	VIII 5,	3	2158844.12	138.68	357.8	+4.23	2158848.35
1277	VIII 9,	4	2187703.17	143.44	0.6	−1.00	2187702.17
1356	VIII 13,	4	2216562.17	148.18	3.3	−6.18	2216555.99
205	years		74870.75				
1561	VIII 7,	22	2291432.92	144.46	357.1	+5.59	2291438.51
1640	VIII 22,	0	2320292.00	149.27	359.9	+0.33	2320292.33
1719	VIII 28,	0	2349151.00	154.00	2.6	−4.85	2349146.15
205	years		74870.71				
1924	VIII 23,	17	2424021.71	150.26	356.4	+6.96	2424028.67
2003	VIII 28,	18	2452880.75	155.02	359.0	+1.74	2452882.49
2082	IX 1,	17	2481739.71	159.73	1.7	−3.40	2481736.31
284	years		103729.75				
2366	IX 3,	11	2585469.46	160.78	358.3	+3.19	2585472.65

The compositions of the cycles are shown, with mean intervals which have attached plus and minus quantities to indicate the margin of variation from the mean.

Julian years	365.25000 × 79 =	28,854.75
Anomalistic periods	686.99565 × 42 =	28,853.82
Synodic periods	779.93600 × 37 =	28,857.63
Mean interval		$28,859.00 \pm 0.^{d}30$
Julian years	205 =	74,876.25
Anomalistic periods	109 =	74,882.53
Synodic periods	96 =	74,873.86
Mean interval		$74,870.80 \pm 0^{d}.40$
Julian years	284 =	103,731.00
Anomalistic periods	151 =	103,736.34
Synodic periods	133 =	103,731.49
Mean interval		$103,730.00 \pm 0^{d}.30$
Julian years	1531 =	559,197.75
Anomalistic periods	814 =	559,214.46
Synodic periods	717 =	559,214.11
Mean interval		$559,214.40 \pm 0^{d}.40$

The 79-year periods can be further subdivided into intervals of 15, 17, 15, 17, 15 years; for example, two 79-year periods beginning with August 18, 1845, that is, 79 years or 28,859 days before August 23, 1924, and ending on August 28, 2003, are taken.

Mars	Opp.	Hr.	G.C.T.	Mag.	☉	Diff. d	Mean π
1845	VIII 18,	15	2395162.62	—2.69	145°46	+12.24	2395174.86
15	years		5446.92				
1860	VII 17,	13	2400609.54	—2.56	115.09	+61.28	2400670.82
17	years		6259.46				
1877	IX 6,	0	2406869.00	—2.68	163.47	—15.22	2406853.78
15	years		5446.25				
1892	VIII 4,	6	2412315.25	—2.67	132.27	+34.50	2412349.75
17	years		6259.17				
1909	IX 24,	10	2418574.42	—2.59	180.71	—41.71	2418532.71
15	years		5447.29				
1924	VIII 23,	17	2424021.71	—2.70	150.26	+ 6.96	2424028.67
15	years		5446.52				
1939	VII 23,	8	2429468.33	—2.59	119.58	+56.31	2429524.64
17	years		6259.63				
1956	IX 10,	23	2435727.96	—2.67	168.18	—20.36	2435707.60
15	years		5446.33				
1971	VIII 10,	7	2441174.29	—2.68	137.00	+29.28	2441203.57
17	years		6258.88				
1988	IX 28,	4	2447433.17	—2.56	185.26	—46.64	2447386.53
15	years		5447.58				
2003	VIII 28,	18	2452880.75	—2.71	155.02	+ 1.74	2452882.49

On August 28, 2003, Mars will be somewhat nearer the earth than it has been for several centuries.

WASHINGTON, D. C.

The Planets in July and August, 1945

NOTE: Greenwich Civil Time is employed unless otherwise stated. To obtain Eastern War Time subtract 4 hours, Central War Time, 5 hours, etc. The phenomena are described as they are to be seen from latitude 45° N. The data are taken chiefly from the *American Ephemeris and Nautical Almanac*.

Sun. During these two months the sun will move eastward about four hours and southward more than fourteen degrees. Its course will be through Gemini and Cancer and into Leo. At the end of August it will be a short distance southeast of the bright star Regulus, which, of course, will be invisible at that time.

Moon. The phases of the moon will occur as follows:

	d	h
Last Quarter	July 2	18
New Moon	9	14
First Quarter	17	7
Full Moon	25	2
Last Quarter	31	22
New Moon	Aug. 8	1
First Quarter	16	0
Full Moon	23	12
Last Quarter	30	4

Mercury. At the beginning of the period, Mercury will be moving eastward more rapidly than the sun. It will reach a point of greatest elongation east on July 23. At this time Mercury will be very near the bright star Regulus, which may serve to identify this planet which can be seen only occasionally. After this date the sun will rapidly overtake Mercury and pass it on August 20. This

date marks the time of inferior conjunction for this planet.

Venus. Venus, having been at a position of greatest elongation west on June 24, will begin the period as a brilliant morning star. It will continue to be a morning star throughout this two months period. Toward the end of the period it will move noticeably nearer to the sun. It will be about 20 degrees north of the equator. It will move eastward from Taurus into Gemini.

Earth. On July 5, the earth will be in aphelion, that is, at the point in its orbit farthest from the sun.

Mars. Mars will continue its eastward course a little more slowly than the sun throughout this period. The result of this difference in motion is Mars will rise earlier from day to day and will be a morning star. At the end of the period it will be cross the meridian just after seven A.M. It will move from Aries into Taurus.

Jupiter. At the beginning of July Jupiter will be nearly five hours east of the sun and at the end of August, less than two hours east. Consequently it will be nearer the western horizon at sunset from day to day. It will be near the equator in declination. It will be in the western part of the constellation Virgo.

Saturn. Saturn will be in conjunction with the sun on July 6. It will, therefore, be hidden in the rays of the sun throughout this period. Its position in the sky will be a short distance south of the Twins in Gemini.

Uranus. Uranus, having been in conjunction with the sun on June 4, will again emerge as a morning star. In fact, like Mars, it will be near the meridian at seven A.M., towards the end of August. It will be in Taurus a short distance northeast of Aldebaran.

Neptune. Neptune will be in favorable position in the evening sky for observation during most of this period. Toward the close it will be rather near the western horizon at sunset. It will be in western Virgo within a half a degree of the equator. It will change its position among the stars very little during these two months.

Occultation Predictions for July and August, 1945

(Taken from the *American Ephemeris*)

Date 1945		Star	Mag.	IMMERSION Greenwich C.T.	IMMERSION a	IMMERSION b	IMMERSION Angle E from N	EMERSION Greenwich C.T.	EMERSION a	EMERSION b	EMERSION Angle E from N
				h m	m	m	°	h m	m	m	°
Occultations Visible in Longitude +72° 30′, Latitude +42° 30′											
July	5	3 B.Taur	6.4	8 47.8	..	..	346	9 0.1	−3.1	−2.4	322
	7	*l* Taur	5.3	8 53.2	..	..	354	9 2.0	−2.6	−3.5	335
	21	123 B.Scor	6.5	3 27.3	−1.8	−0.7	80	4 42.8	−1.4	−1.9	304
	23	24 Sgtr	5.7	6 12.6	−2.3	−3.1	146	6 48.9	+0.1	+1.1	205
	26	128 B.Capr	6.5	7 5.1	−1.9	−0.5	91	8 13.5	−0.8	+0.3	222
	27	56 Aqar	6.4	9 28.1	−1.1	−0.4	68	10 34.9	−0.6	−0.3	237
	29	24 B.Ceti	6.0	4 27.9	−0.5	+2.5	19	5 15.8	−1.4	+0.8	288
Aug.	17	116 B.Ophi	6.3	23 8.1	−2.9	+2.0	53	23 58.9	−1.1	−2.0	342
	28	85 Ceti	6.3	7 54.1	−1.4	+1.4	60	9 9.9	−1.6	+1.0	239
	29	30 B.Taur	6.5	7 28.9	−0.7	+2.2	42	8 36.7	−1.8	+0.8	265
	31	BD+21°918	6.3	10 15.2	−1.8	+0.5	95	11 32.2	−1.7	+1.5	239

OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′

July	6	193	B.Taur	6.3	9	51.7	−0.1	+1.5	72	10	49.3	−0.4	+1.7	245
	21	123	B.Scor	6.5	2	48.7	−2.3	−0.1	94	4	15.8	−1.9	−1.4	300
	23	24	Sgtr	5.7	5	36.9	−2.2	−1.6	133	6	36.5	−1.2	+0.4	224
	26	128	B.Capr	6.5	6	28.6	−1.9	+0.7	76	7	49.4	−1.7	+0.4	242
	27	56	Aqar	6.4	9	4.4	−1.3	+0.7	47	10	17.4	−1.5	−0.4	255
	28	336	B.Aqar	6.5	11	26.1	−1.4	−0.4	75	12	31.9	−0.6	+0.3	224
	29	24	B.Ceti	6.0	4	14.0	−0.3	+2.4	23	4	56.2	−0.5	+0.8	292
Aug.	19	1	Sgtr	5.1	5	46.6	−1.4	−1.7	111	6	51.0	−0.3	−0.6	242
	25	30	Pisc	4.7	9	48.0	−2.5	−2.2	113	10	28.7	0.0	+2.6	183
	28	85	Ceti	6.3	7	30.2	−0.7	+2.2	39	8	36.5	−1.7	+1.0	261
	29	30	B.Taur	6.5	7	16.7	+0.1	+2.8	18	8	2.6	−1.7	+0.5	289
	31	BD+21°918		6.3	9	46.2	−1.0	+1.4	80	10	59.0	−1.4	+1.6	248

OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′

July	17	80	Virg	5.8	5	12.0	−1.0	−2.4	140	6	20.6	−0.8	−1.4	273
	21	123	B.Scor	6.5	2	2.5	−0.6	−0.7	143	3	14.2	−2.4	+0.9	265
	23	24	Sgtr	5.7	4	49.7	−0.7	−2.1	158	5	31.9	−3.0	+2.7	217
	23	26	Sgtr	6.1	9	27.6	−1.5	−1.1	95	10	39.1	−0.6	−0.6	251
	26	128	B.Capr	6.5	5	36.4	−1.1	+1.3	80	6	51.5	−1.7	+1.2	255
	27	56	Aqar	6.4	8	20.6	−1.2	+2.8	15	9	13.0	−2.9	−0.6	295
	28	336	B.Aqar	6.5	10	40.3	−1.4	+1.6	39	11	55.7	−2.0	+0.1	256
Aug.	3	312	B.Taur	6.2	9	43.2	−0.2	+0.3	121	10	17.9	+0.6	+2.5	203
	19	1	Sgtr	5.1	4	55.8	−2.3	−0.6	102	6	23.2	−1.8	−0.6	262
	21	329	B.Sgtr	6.1	2	5.1	..	..	21	2	30.4	+0.4	−2.6	339
	25	30	Pisc	4.7	8	44.6	−1.8	+1.0	68	10	0.4	−1.4	+1.3	225
	25	33	Pisc	4.7	11	14.9	..	..	134	10	30.4	..	..	158
	28	85	Ceti	6.3	7	16.8	+0.4	+3.0	8	7	48.9	−1.3	+0.1	300
	31	BD+21°918		6.3	9	28.5	+0.2	+1.8	52	10	23.7	−0.7	+1.0	276

OCCULTATIONS VISIBLE IN LONGITUDE +98° 0′, LATITUDE +30° 0′*

July	5	3	B.Taur	6.4	8	21.4	+0.9	+3.8	357	8	38.7	−0.6	−1.5	318
	6	193	B.Taur	6.3	9	39.2	+0.1	+1.0	85	10	31.2	0.0	+1.7	232
	21	123	B.Scor	6.5	2	36.9	−2.1	−0.8	123	4	10.7	−2.6	−0.7	278
	23	24	Sgtr	5.7	5	47.5	..	..	168	6	7.6	..	..	192
	23	117	B.Sgtr	5.8	8	25.6	−0.4	+1.0	38	9	16.8	−1.5	−2.4	307
	26	128	B.Capr	6.5	6	7.3	−2.2	+0.5	91	7	28.1	−2.0	+1.3	230
	27	56	Aqar	6.4	8	44.2	−2.0	+1.0	59	10	6.1	−1.7	+0.5	241
	28	336	B.Aqar	6.5	11	18.9	−2.4	−0.8	94	12	18.2	−0.4	+1.8	199
Aug.	19	1	Sgtr	5.1	5	53.9	−2.2	−2.4	130	6	48.9	−0.2	+0.7	222
	21	329	B.Sgtr	6.1	2	40.5	..	..	8	2	59.8	..	..	343
	26	26	Ceti	6.2	14	18.8	−0.3	+1.1	31	15	5.5	−0.1	−1.3	280
	28	85	Ceti	6.3	7	5.0	−0.6	+1.9	50	8	12.8	−1.4	+1.4	249
	29	30	B.Taur	6.5	6	52.2	+0.1	+2.2	33	7	45.8	−1.1	+0.9	274
	31	BD+21°918		6.3	9	27.7	−1.0	+0.8	97	10	31.5	−0.8	+2.3	228

*Computed by Edgar W. Woolard and Paul Herget; communicated by Commodore J. F. Hellweg, Superintendent U.S. Naval Observatory.

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

Asteroid Notes

By HUGH S. RICE

We are continuing the asteroid ephemerides of the last issue, for the purposes of early summer observations. All three objects are in a good place for evening work, and are not far from one another in the sky. We have been observing Vesta and Ceres especially, which, together with Pallas, are always among the easiest of the minor planets to observe. With the last appearance of the asteroids during this "apparition," the series "runs out," and we shall have to await the appearance of other planets to take their place.

EPHEMERIDES OF MINOR PLANETS FOR 0^h U.T.

2 PALLAS

1945	α h m	δ ° ′	1945	α h m	δ ° ′
July 4	12 28.6	+18 1	July 19	12 46.3	+16 29
9	12 34.3	+17 32	24	12 52.5	+15 56
14	12 40.2	+17 1	29	12 58.8	+15 22

4 VESTA

1945	α h m	δ ° ′	1945	α h m	δ ° ′
July 4	13 8.9	+ 0 33	July 24	13 31.4	— 3 4
9	13 13.9	— 0 19	29	13 38.0	— 4 1
14	13 19.4	— 1 13	Aug. 3	13 44.8	— 4 58
19	13 25.2	— 2 8	8	13 52.0	— 5 56

1 CERES

1945	α h m	δ ° ′	1945	α h m	δ ° ′
July 4	13 48.9	— 3 51	July 29	14 5.2	— 7 16
9	13 51.3	— 4 30	Aug. 3	14 9.6	— 8 0
14	13 54.1	— 5 10	8	14 14.4	— 8 44
19	13 57.4	— 5 51	13	14 19.5	— 9 28
24	14 1.1	— 6 33	18	14 24.8	—10 12

Hayden Planetarium, American Museum of Natural History, New York, May 23, 1945.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

The Recurrent Nova, T Pyxidis: After years of patient watching on the part of a few observers, particularly J. M. Baldwin of Australia and H. E. Houghton of South Africa between the two world wars, Nova Pyxidis has presented its fourth outburst during the past half century.

This long expected news came through from Mount Wilson Observatory early in April, stating that Dr. A. H. Joy had found the nova three magnitudes above normal minimum brightness, which, if we assume the minimum magnitude to be about fourteen, would make the magnitude when observed by Joy about eleven.

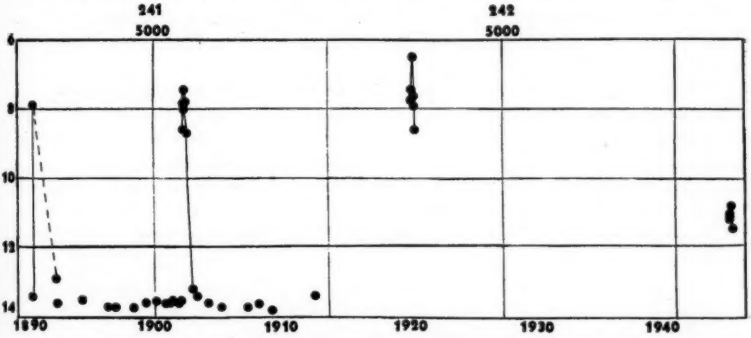
It was not known whether or not the nova was at the pre- or post-maximum stage, and requests were sent out to observe the nova at once. Soon Joy reported

that later photographs revealed that the spectrum of the nova showed post-maximum conditions, and the contemporaneous visual and photographic observations of the magnitude confirmed this conclusion, since from April 11 through 19, the brightness has decreased from 10.8 to 11.2; not an increase, as had been hoped for.

T Pyxidis was originally discovered by Miss Leavitt on the occasion of its 1902 maximum, when the star attained a maximum brightness of 7.4. Since it was suspected, from the appearance of its spectrum, as being a nova, a search through earlier Harvard plates revealed that it had been bright in 1890, twelve years previously. Although the 1890 maximum depends on only one observation, there is no doubt of the reality of the image as being stellar, and that the magnitude at that time was 7.9.

The 1920 maximum was detected by Miss I. E. Woods, and a summation of all the Harvard photographic observations from 1890 to 1920 inclusive was printed in Volume 84 of the *Annals*. Accordingly, we now have evidences that Nova (T) Pyxidis was bright in the years 1890, 1902, 1920, and 1945. The intervals in years between these outbursts are of interest: 12, 18, and 25, respectively. If we can make any prediction whatever, the next outburst should occur about 33 years hence, or in 1978, but on this event happening then, one can place little, if any, confidence.

The accompanying figure illustrates, on a very restricted scale, the four observed maxima—on the photographic scale of magnitude. Observations at minimum between the third and fourth maxima have not been plotted, but the occasional visual estimates which were made during this interval of time show that the nova was not brighter than approximately the fourteenth magnitude.



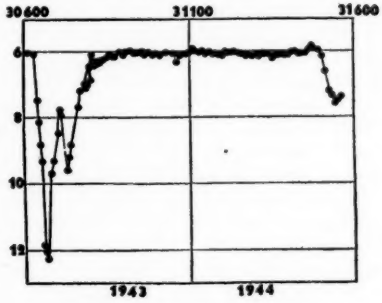
Four Maxima of Nova (T) Pyxidis
(Photographic Magnitudes)

It is hoped that when plates have been received from South Africa we may find on a plate or two some further evidence as to when the maximum of 1945 was actually attained, and how bright the nova was at that time.

R Coronae Borealis: This well-known erratic variable, as reported in these notes for April, began a descent to minimum late in February, but the star did not decrease in light by more than two magnitudes, not below the magnitude 7.6, at least. The latest reports indicate that the variable is increasing in brightness again. It may continue to increase further, or it may suddenly fade away to a very faint minimum. Time only will tell!

The light curve depicting the variation since September, 1942, is shown in the figure. It will be noted that in the 1942-43 minimum, the star faded rapidly to magnitude 12.3, then brightened almost as rapidly to magnitude 7.8, after which it decreased to 9.6. From then on, the star rose steadily to its normal maximum at magnitude 6.0.

A point of interest is the slight increase in brightness in January of this year to magnitude 5.8, just prior to the start of its recent descent. This particular feature has been noted on several previous occasions.



LIGHT VARIATIONS OF
R CORONAE BOREALIS (1943-45)

Supernova Near NGC 5195: Another supernova has been detected in a galaxy, NGC 5195, the companion nebula to Messier 51, the Great Spiral Nebula in Canes Venatici. It was discovered by Mr. Milton Humason on a Mount Wilson photograph taken on April 7 of this year.

Unfortunately, it was found while in the post-maximum stage, probably 65 days after maximum brightness had been reached. This fact is borne out by subsequent spectrum plates which clearly indicate that the bands in the photographic region have decreased in strength because of obscuration in the system.

The magnitude of the nova was estimated by Dr. Baade on April 12 as 16.0 photographic, 14.0 photovisual, and 13.5 red. Its probable magnitude at maximum is estimated to have been 11.0 photographic; perhaps even brighter, as seen visually.

Alpha Orionis-Betelgeuse: Recently, attention has been called to the unusually faint magnitude of Betelgeuse, not only in England by Mr. P. M. Ryves, but also in this country by Mr. D. W. Rosebrugh. Since the beginning of the year the star, usually somewhat brighter than magnitude 1.0, has been around 1.3 or 1.4.

To be sure, Betelgeuse is not now favorably placed for observation, but when it does become available, it is desirable that observations of brightness be made at regular intervals. Although it is a very red object, and therefore more difficult to observe than most other bright stars, if care is used to compare Betelgeuse with such stars as Aldebaran, Castor, and Pollux, satisfactory results may be obtained. With such a bright object, of course, straight naked-eye estimates should be made. Better still would be photo-electric measures at some regular observatory so equipped.

The following comparison stars will be found useful in estimating the brightness of this variable, but care should be taken to make comparisons with those

stars which are at not too great a difference in altitude.

Capella (α Aur)	0.2	Pollux (β Gem)	1.2
Procyon (α CMi)	0.5	Castor (α Gem)	1.6
Aldebaran (α Tau)	1.1		

Observations for March and April: A total of 5337 observations—2369 in March and 2968 in April—were contributed by 44 observers, as listed herewith.

Observer	March No. Var.	March No. Ests.	April No. Var.	April No. Ests.	Observer	March No. Var.	March No. Ests.	April No. Var.	April No. Ests.
Blunck	5	8	...	...	Mary	15	78	23	67
Boone	...	...	18	19	Mount	11	17	13	36
Bouton	26	32	29	42	Nadeau	63	63	...	...
Buckstaff	...	...	13	19	Oheim	44	65	48	86
Cousins	42	100	34	60	Oravec	10	35	9	28
Cragg	14	56	34	102	Parker	...	...	20	20
Dafter	...	...	7	15	Parks	25	42	21	38
Duffie	...	...	21	27	Peltier	133	166	88	129
Fernald	231	426	231	623	Reeves	1	2	...	...
Ford	5	5	50	51	Renner	20	20	...	...
Gossner	36	71	16	23	Rosebrugh	17	141	20	127
Harris	14	14	32	32	Segers	20	62	...	...
Hartmann	114	127	129	147	Sill	26	26	69	70
Holt	99	117	118	155	Stowe	...	...	20	51
Houston	7	7	...	...	Taboada	...	...	29	37
Howarth	15	15	...	...	Taulman	69	74	3	3
Itzigsohn	...	...	55	395	Topham	...	...	5	5
Kearons	32	64	...	...	Volman	...	...	14	14
Kelly	11	19	11	15	Webb	24	32	16	21
de Kock	65	327	65	296	Weber	30	30	20	20
Koons	...	...	54	96	Weitzenhoffer	2	7	...	...
Liller	37	60	15	20					
Luft	12	60	14	79	Totals		2369		2968

May 11, 1945.

METEORS AND METEORITES

Contributions of the Society for Research on Meteorites

Edited by **FREDERICK C. LEONARD**
Department of Astronomy, University of California, Los Angeles 24

Some Observations on the Soil near the Canyon Diablo, Arizona, Meteorite Crater

JOHN DAVIS BUDDHUE
99 South Raymond Avenue, Pasadena 2, California

ABSTRACT

Four samples of soil from 2 places approximately 2 miles from the Canyon Diablo, Arizona, Meteorite Crater contain no nickel or fragments of oxide, but material resembling volcanic ash is fairly abundant. The *pH* of the soils is near 8.5. This mild alkalinity would tend to help the irons resist corrosion. One partial analysis is given.

The soils used in this investigation were collected at my request by Dr. Frederick C. Leonard in October, 1944. The sources of the samples were as follows:

1 and 2: about 1¾ miles west of the Crater rim, near the place where an 8-lb. meteorite was found underground.

3 and 4: about 2 miles northwest of the Crater rim, near the "Red Hills."

The odd-numbered samples were taken from the surface, while the even-numbered ones came from a depth of 6 to 12 inches.

It was thought that when the meteorite that formed the Crater landed, a sort of fog or rain of droplets of iron might have been produced by the impact-explosion. If so, nickel might still be found in the soil around the Crater. From the geology of the Crater, the west or northwest sectors were perhaps most likely to receive such matter if any was produced. The samples at hand came from localities which may be somewhat far removed from the Crater to test this hypothesis, but no other samples are at present available.

A part of sample 1 was worked over with an alnico magnet. Alnico magnets are unusually powerful and will attract even feebly magnetic particles. The magnetic and non-magnetic portions were then subjected to partial analyses with the following results:

Non-magnetic Material		
$CaCO_3$	4.14%	
Fe_2O_3	6.47	
NiO	nil	
Sand	70.69	
		81.30%
Magnetic Material		
$Fe_2O_3 + FeO$	0.55%	
NiO	nil	
Soluble silica	0.35	
Insoluble	10.72	
Not det.	7.08	
		18.70%
		100.00%

The magnetic portion was, for the most part, only feebly magnetic, and it did not have the appearance of small fragments of oxide; rather, it looked like pieces of wind-worn, vesicular, black lava. Mr. L. F. Brady of Tempe, Arizona, says in a private letter that there are small, fairly recently volcanic cones, 15 to 20 miles from Meteorite Crater, which might have been the source of volcanic ash, and that ash from Sunset Crater was carried about 40 miles. Moreover, the ash from these craters is feebly magnetic. At Mr. Brady's suggestion, some of the magnetic material was embedded in plastic and then cut into thin sections. These seemed to indicate definitely that the material is volcanic ash. It is far from being entirely vitreous, and this fact, coupled with the absence of any nickel, seems to indicate that it is not an impact glass such as was formed at Wabar, Arabia, and Henbury, Central Australia.

Since this analysis revealed nothing of particular interest, the other samples were not examined so completely. None of them contained any nickel, and all contained about the same amount of magnetic material. The absence of nickel shows that, if there was ever any meteoritic matter in the samples, it has all been leached out by the rain and carried more than a foot below the surface. Sample 2 contained much more carbonate (26.40% $CaCO_3$) than the sample (No. 1)

directly above it.

Since I am interested especially in the oxidation of meteorites, I was interested in the *pH* of these soils in their moist state, since this quantity is of great importance in the rapidity of corrosion. The *pH* was determined by adding distilled water to samples of the soil in sufficient quantity to form a thin mud. The *pH* was then determined with a Beckman *pH*-meter, at intervals, until 2 successive readings were identical. The *pH* and colors of the samples were:

Sample	*pH*	Color
1	8.59	4 YR 6/4
2	8.45	
3	8.32	10 R 4/6
4	8.39	

The mildly alkaline nature of the soil would be expected in an arid region, especially since the formation of the Crater must have added much pulverized limestone to the soil for some distance around. This *pH* is such as to prevent rapid corrosion, provided it is not counteracted by other factors.

The colors are given in the preceding table in the well-known Munsell terminology and are only approximate. In the more familiar terminology of Faber Birren's *The American Colorist* (The Crimson Press, Westport, Connecticut, 1939), samples 1 and 2 are "orange, pale dull tone," and samples 3 and 4 are "red, pale grayish tone."

On the Case of the Willamette, Oregon, Siderite

In the current April and May instalments of *C.S.R.M.*, has not the author of the paper entitled, "A Legal Treatise on Meteorites; or, Did You Ever See a 'Tomanowas'?", in writing on the law suit regarding the Willamette, Oregon, siderite, interchanged the plaintiff and the defendant? The party from the University of Oregon, which, in 1938, went to Willamette and interviewed old Mr. Ellis Hughes, the discoverer of the meteorite, and likewise the descendants of some others connected with the case, obtained the opposite impression from that conveyed in the forenamed paper.

My latest article on this subject appeared in *Sky and Telescope*, **2**, No. 7, 6-7, 1943. This carried (on p. 6) a photograph of the meteorite in transit thru the woods and (on p. 7) a picture of Mr. Hughes taken in 1938, while the outside of the back cover was decorated with beautiful reproductions of my 2 pieces (polished-and-etched sections) of the great siderite. One of my earlier papers on the same subject appeared in *C.S.R.M.*, **2**, 85-7; *P. A.*, **47**, 148-50, 1939. The reader is referred to these articles for further details concerning this interesting case and also to a note published in *C.S.R.M.*, **3**, 79; *P. A.*, **51**, 167, 1943.

J. Hugh Pruett

University of Oregon, Eugene, 1945 April 21

Boris Slanin, 1920-1944

It is my sad, my very sad, duty to record that Boris Slanin, formerly a major student and an assistant in the Department of Astronomy of the University of California, Los Angeles, and a member of the Society for Research on Meteorites, was killed in action in a small town about 16 miles east of Frankfurt, Germany, on May 12, 1944. Altho he was then reported as missing, news of his death was not received by his family until April 8, 1945.

Boris, as we knew him, left the University and entered the service of his country on January 5, 1942. At the time of his death he held the rank of Captain in the Army Air Force, being the pilot of a B17 bomber named *Lady Stardust II*. He was born on December 17, 1920, in Los Angeles, California, where he received his entire education prior to joining the Army. He is survived by his wife, Mrs. Helen Rice Slanin, of Odessa, Texas, whom he married in Los Angeles on June 15, 1943, and by his parents, Mr. and Mrs. Nicholas Slanin, and his sister, Miss Ludmela Slanin, of Los Angeles. In the course of the time that he was in the service, he was awarded an air medal with two oak-leaf clusters. He will be remembered by the readers of *C.S.R.M.* as the co-author of several of our "Statistical Studies of the Meteoritic Falls of the World." His tragic and untimely death has terminated an unusually promising career and brought to a close a life that was a joy and an inspiration to all his friends and associates. His passing is the greatest personal loss that we in the Department of Astronomy here have sustained in World War II.

FREDERICK C. LEONARD

Recent Meteoritical Literature

(1) Attention is called to a paper in *Jour. Geol.*, **53**, 66-7, 1 fig., 1945, by John C. McCampbell of Rutgers University, New Brunswick, New Jersey, on "A Geomagnetic Survey of Some Bladen County, North Carolina, 'Carolina Bays.'" The final paragraph of the article reads as follows:

"Altho previous reports of similar surveys have relied upon such magnetic data as presented here as a conclusive proof of the meteoritic hypothesis of origin of the bays, the question is here left open and the reader is free to arrive at any conclusion as to their origin that may be warranted by the facts presented."

For an exhaustive account of the alternative "hypothesis of complex origin," or "artesian-solution-lacustrine-aeolian hypothesis," the late Douglas Johnson's *The Origin of the Carolina Bays*, Columbia Univ. Press, 1942, should be consulted.

(2) Stuart H. Perry's valuable publication entitled "The Metallography of Meteoric [*sic*] Iron" (*U.S. Natl. Mus. Bull. 184*, 206 pp., 81 pls., 1944, price $0.60) is excellently reviewed by Lincoln La Paz in *P. A.*, **53**, 99-101, 1945.

(3) Following is the summary of "An Analysis of British Meteor Data: Part 2. Analysis," by J. G. Porter, in *Mon. Not. Roy. Astron. Soc.*, **104**, 257-72, 2 figs., 1944:

"The material is classified and grouped for analysis (§§ 1-3). The discussion of errors and their correlations leads to the important conclusion that errors of all types tend to increase with the length of path and the brightness of the meteor (§§ 4-7). Correlations between the various physical quantities are tabulated (§ 8). A comparison of data for the main showers and for all other meteors shows that, if the comparison is made in accordance with the rules of statistical analysis, there is no essential difference between the data for shower and non-shower meteors. In particular, the heights of comparable groups are significantly the same, and the so-called seasonal effect is really of a statistical nature (§§ 9-12). A study of observed speeds leads to the definite conclusion that the low speeds as given by observers are real, and that meteor[ite]s are retarded by the atmosphere before they become visible. A reasonable explanation of the anomalous appearance of telescopic meteors is thus afforded (§§ 13-17). The complete absence of any direct evidence in support of the supposed excess of hyperbolic velocities among meteor[ite]s is significant. Apart from a few exceptional cases,

all meteor[ite]s are members of the solar system, and behave as such (§§ 18-20)."

(4) "Geology Applied to Selenology: The Imbrian Plain Region of the Moon," by J. E. Spurr, viii + 112 pp., 4 pls., 23 figs., published and copyright by the author, 1944 (The Science Press Printing Company, Lancaster, Pennsylvania). The author scouts the meteoritic hypothesis of the origin of the lunar craters, which he considers only in a brief "Addendum" (pp. 109-10), and embraces the volcanic hypothesis, or a modification of it (*cf.* the "Summary," p. viii).

F.C.L.

President of the Society: LINCOLN LA PAZ, Department of Mathematics, Ohio State University, Columbus 10

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Comet Notes

By G. VAN BIESBROECK

At the time of writing no comets are known to be observable in ordinary telescopes. However since the last report two expected periodic comets have been recovered and since both are brightening up somewhat they may come in reach for visual observers.

The first of these is PERIODIC COMET PONS-WINNECKE which was recovered by H. L. Giclas at the Lowell Observatory, Flagstaff, Arizona. The position was:

1945 MAY 3.2264 U.T.

Right ascension	$12^h\ 59^m\ 30^s.1$	Magnitude 14
Declination	$+45°\ 22'\ 7''$	

DIFFUSE OBJECT WITH NUCLEUS

Comparison with the English ephemeris reproduced in the March issue (p. 140) indicates that the comet comes to perihelion 2½ days later than computed. This puts it nearly four degrees away from the predicted position and accounts for the earlier failures in locating the object with powerful but small-field photographic telescopes.

With the modified perihelion time the ephemeris can now be corrected as follows for the short duration of the visibility to northern observers:

1945	h m	° ′	Mag.
June 6	12 52.5	+32 29	13.2
10	55.5	29 36	13.1
14	12 59.7	26 34	12.9
18	13 3.8	23 14	12.8
22	9.1	19 40	12.7
26	15.1	15 44	12.6
30	21.8	11 33	12.6
July 4	29.3	7 8	12.5
8	37.6	+ 2 23	12.5
12	46.9	— 2 29	12.5
16	13 57.0	— 7 29	12.5

The magnitude is deduced from the distance relations, starting from Giclas' magnitude of 14 for May 3. Visibility will be limited to the first part of the night. During this time the comet moves from Canes Venatici to Virgo but after that visibility will be better for observers in the southern hemisphere who will be able to follow the comet for several months longer.

This six-year-period comet has now been seen at every return since 1909 but

at the present one it comes only within 0.4 astronomical units of the earth which reduces the brightness considerably as compared with recent apparitions.

Credit for the recovery of the second expected comet also goes to H. L. Giclas at the Lowell Observatory. This is COMET KOPFF which has also a six-year period. It was first discovered at Heidelberg in 1906 and was only missed at one opposition since that time. The first observation gave:

1945 MAY 7.38208 U.T.

Right ascension	$15^h\ 0^m\ 11^s.9$
Declination	$-24°\ 27'\ 21''$,

and recorded the comet as being of magnitude 13, diffuse and with a nucleus. This location is nearly two degrees away from the ephemeris by W. E. Beart and W. P. Henderson (*Handbook of the British Astr. Assoc.*, 1945, p. 35) but this deviation was not too large for the Flagstaff observer using a large-field photographic telescope. Before this information was broadcast a mimeographed ephemeris by F. Kepinski was received at the McDonald Observatory and this enabled the writer to locate the comet at once. Plates taken with the 82-inch reflector there showed the object in the location:

1945 May 12.2727 U.T. $14^h\ 57^m\ 15^s$, $-23°\ 45'.4$.

It had a stellar nucleus of about 14th magnitude surrounded by a coma 10 to 15 seconds of arc in diameter, the total light-impression corresponding to a star between 12th and 13th magnitude. There was besides a faint tail extending northward over 1′ from the nucleus.

F. Kepinski has for years followed the motion of this object and previously predicted its position very accurately. Once more the present position corresponds exactly to the ephemeris, a remarkable prediction after an interval of six years since the last apparition. Perihelion occurs 1945 August 11.294. It was comforting to find this Polish astronomer still active in Warsaw, at least on March 3, 1944, in spite of the tragic ordeal of his country. The following continuation of Kepinski's ephemeris should make it possible to locate the object readily:

1945	h	m	°	′	Distance from Earth	Distance from Sun	1945	h	m	°	′	Distance from Earth	Distance from Sun
June 4	14	46.6	−19	38	0.69	1.65	July 4	15	0.2	−15	16	0.72	1.55
9		46.1	18	43			9		6.4	14	53		
14		46.7	17	50	0.69	1.61	14		13.6	14	36	0.75	1.52
19		48.4	17	3			19		21.8	14	25		
24		51.2	16	21	0.70	1.58	24		30.9	14	19	0.78	1.51
29	14	55.1	15	45			29		40.9	14	17		
							Aug. 3	15	51.6	−14	19	0.83	1.50

The comet moves slowly across the constellation of Libra and is not expected to become much brighter than 12th magnitude. Maximum light is due in July.

Of the previously announced comets two extremely faint objects have been under observation. They are COMET VAN GENT (1944 *d*) for which G. H. Herbig has computed an extension of the ephemeris (*P.A.S.P.*, **57**, 99, 1945) and PERIODIC COMET OTERMA, mentioned last month. The former was recorded by the writer as a tiny coma as faint as 18th magnitude on May 8. The latter is not much brighter.

Another comet that will probably be located before long is PERIODIC COMET VÄISÄLÄ (1944 *c*) but it will be very faint.

Williams Bay, Wisconsin, May 29, 1945.

Communications and Comments

Under this heading we shall publish from time to time such material as does not properly fall under any of the established headings of this journal. Here, too, may be found, when occasion arises, articles which the editor may not be willing to give sanction to but which, nevertheless, may be provocative of thought along new lines.

The Calendar and the Tropical Year

The Tropical Year, sometimes called the year of the seasons, is the standard by which the accuracy of any calendar must be measured. In the *American Ephemeris* we find these data: Length of the Tropical (ordinary) Year

$$365.24219879 - 0.0000000614\ (t - 1900) \text{ mean solar days,}$$

and General Precession,

$$50''.2564 + 0''.000222\ (t - 1900).$$

The Tropical Year begins when the mean sun is at the tropical colure or celestial longitude 270° (winter solstice). The time of this occurrence may be obtained from the *American Ephemeris*. According to page 18 of the volume for 1946, the sun's mean longitude for December 22 is 269°.9553, and $(270 - 269.9553)/.98565^* = .0453$, giving December 22.0453, Greenwich Civil Time, as the beginning of the year 1947. Changing this to the Julian Day we have 2432176.5453 which corresponds to the time of the International Date Line and to the Zero (or Prime) Meridian of Standard Time. By adding the length of the year, as given above, to this Julian Day we obtain the following table which shows the times of the beginning of the Tropical Year in Julian Days and the corresponding calendar dates thru a complete precessional cycle. By changing the formula for precession from seconds to degrees we get $0°.0139601 + 0°.0000000616\ (t - 1900)$. From this the amounts of precession are found as shown in the fourth column of the table.

THE CYCLE OF PRECESSION

Tropical Year	Julian Day	Calendar Date*			Precession
0	1677586.0375	B.C.	121	Dec. 25W	0°.0000
75	1704979.2116		46	Dec. 25F	1.0378
100	1714110.2695	B.C.	21	Dec. 25M	1.3839
200	1750634.5008	A.D.	80	Dec. 23Sa	2.7684
400	1823682.9617		280	Dec. 21Tu	5.5392
1000	2042828.3296		880	Dec. 17Sa	13.8665
1600	2261973.6753		1480	Dec. 12Tu	22.2160
1702	2299228.3819		1582	Dec. 22W	23.6376
1900	2371546.3399		1780	Dec. 21Th	26.3990
2000	2408070.5602		1880	Dec. 21Tu	27.7946
2020	2415375.4042		1900	Dec. 22Sa	28.0738
2060	2429985.0921		1940	Dec. 22Su	28.6322
2065	2431811.3031		1945	Dec. 22Sa	28.7021
2080	2437289.9360		1960	Dec. 21W	28.9115
2100	2444594.7799		1980	Dec. 21Su	29.1908
3000	2773312.7295		2880	Dec. 20F	41.8146
4000	3138554.8374		3880	Dec. 20M	55.8359
6000	3869038.8689		5880	Dec. 19Su	84.1238
8000	4599522.6548		7880	Dec. 18Sa	112.6583

*0°.98565 is the mean sun's daily change in longitude.

*Julian Calendar before A.D. 1582 Oct. 5 Friday, afterwards Gregorian Calendar.

Tropical Year	Julian Day	Calendar Date*	Precession
10000	5330006.1951	9880 Dec. 17F	141.4394
12000	6060489.4898	11880 Dec. 15W	170.4671
14000	6790972.5389	13880 Dec. 13M	199.7414
16000	7521455.3424	15880 Dec. 11Sa	229.2623
18000	8251937.9003	17880 Dec. 8W	259.0298
20000	8982420.2126	19880 Dec. 6M	289.0440
22000	9712902.2793	21880 Dec. 3F	319.3047
24000	10443384.1004	23880 Nov. 30Tu	349.8120
24664	10685904.0115	24544 Nov. 29Su	359.9949

This table is an epitome of the progress of the calendar. It shows that, when Caesar established the Julian calendar, the solstice occurred on December 25 which was taken as the date of Christmas. In 1582, Pope Gregory made a new Leap Year Rule. He failed to restore Christmas to the time of the solstice. He wished only to bring back the calendar to its position at the time of the Council of Nicaea (A.D. 325), but it might have been better if he had restored Christmas to the time of the solstice. And, similarly, it might have been better had Caesar begun the year at the time of the solstice instead of the time of the new moon that followed the solstice of the year B.C. 46.

There is still an error in the Gregorian Leap Year Rule. When applied to a long period of time such as the cycle of precession, the error will accumulate until the first of January will occur 32 days after the solstice instead of 10 days as is now the case.

H. Porter Trefethen.

Winthrop, Maine.

An Annual Summary of Astronomical Progress

Introduction

Since astronomical papers are published in the chronological order of astronomical progress and often in publications without wide circulation, they are in too many cases either missed when released or later become buried in the literature. Therefore it is proposed that an annual publication be prepared that could conveniently and economically bring together into a single master issue, from all sources, an orderly summary of recent progress. Furthermore, because the annual would correlate current changes and incorporate them into the body of astronomical knowledge, it could be undeniably useful as a basic astronomical reference, authentic, complete, and currently corrected in all its aspects.

The double problems of the needless duplication of scientific research and the misunderstanding caused by the time lag between such research and its general acceptance, have a common solution. This solution for preserving and making available such source material is commercially self-sustaining because it considers not only the problems of the scientific worker, but also those of all laymen interested in such research.

Taking as example the oldest science and one that is especially adapted to such a reference work, I outline a program by which astronomical research may be compiled and credited to the authors, in ways that allow all interested workers to locate and refer instantly to source material. Naturally the value and exact nature of such a guide depend upon the different uses to which it could be put, and I find at least ten. If your interest is not in astronomy, the science of your preference may be substituted as you study these ten uses.

First, in order to make it commercially practicable, this publication must

serve as a basic astronomical reference. Thus it will follow the topical outline standard to textbooks, starting under each topic with a historical summary and indicating the trend of latest years. Going beyond the contents of the usual textbook, the topical development will have a summary of all reasonable theories accounting for the facts.

Second, the complete argument for and against each theory will be compared point by point in a double column, and authorities cited for each point. This will be followed by naming the outstanding advocates and opponents of each theory and by graduated statistics as to how the theory fares among specialists and others who have done lesser research in it or allied topics. Because of the ease with which both sides could be studied, it should hasten abandonment of faulty theories and general acceptance of better ones.

Third, when a specialist establishes new facts in one science, it should hasten the corresponding change in other sciences influenced by it. Thus wherever possible the summary must show relationship between astronomy and other sciences, and check each phase by the result of research in allied sciences. "When we reflect that so eminent a geologist as M de Lapparent espoused M Blondet's hypothesis," wrote Lowell of a theory astronomically impossible, "we see how necessary to geological conceptions is a foundation for them in astronomy." Until a similar geological summary is compiled it would be useful to have a geological supplement with facts pertinent to astronomy.

Fourth, each topic will be followed by reference to source documents and later discussions, the most important of which will either be under the topic itself or in a separate section. In this section will be extracts from the classical source documents, and a summary of present research composed of original and reprinted articles of importance and digests of society proceedings.

Fifth, the guide will simplify research by having reference leads on all astronomical information, and eliminate needless duplication of efforts by its summary of research work of the world, completed and in progress. Each topic will be followed by a short list of specialists, merely the name and a brief statement of the research each is doing or did in it, so that other workers may know who is doing similar work and to whom they may turn for special help. This location might logically be used by a scientist, who, for instance, is collecting and classifying meteorites, to request readers to forward to him meteorites that they find.

Sixth, the guide will call attention to needs for further research and possible funds open for research, and list astronomical problems most needing financial help, as revealed within its pages. For those willing to contribute, it would name persons who could do the research.

Before I go further let me explain that since this annual is for reference only, it will be more condensed than any publication meant to be readable, and so in turn be more nearly complete. But to avoid needless duplication and bulk, it must be balanced to use with specific standard and indispensable manuals such as the *Nautical Almanac* and a star atlas. The supplement in the guide will have a bibliography of technical books and instructions on how to use them. Each topic in the guide will normally be followed by an identity list of objects and localities concerned, but cross-reference could be given instead of specific pages in these manuals.

Seventh, so that public credit may be given, each scientific advance will be credited to its author. Any honor, such as the listings of the leading astronomers

by their society, or other recognitions given individual men, will be included, followed by a brief summary on each living astronomer: name, address, birth, education, societies, awards, present research, and unaccepted contributions which he thinks merit continued reflection. Included also will be obituaries of scientists who have passed away since the last edition was published. Mainly for republication, will condense biographical sketches of the great scientists and insert alphabetically in the biographical section, giving as much dramatic and striking material for reuse in news articles as is authentic.

Eighth, it will have a calendar of anniversaries of scientists' births and discoveries, and announce coming events to attract scientific attention, so that editors can have material prepared in advance.

Ninth, it should bring astronomers into closer unity to overcome difficulties in the way of scientific advance, by reporting on the progress of astronomy, favorable and unfavorable educational facilities, the distribution of astronomical buildings and amateur clubs, and public reception and misconceptions of astronomical theories.

Tenth, and quite important as much of the backing given research depends upon public support, it will act as a clearing house of information for writers and other interested laymen, and eliminate many inaccuracies. In it will be the complete background for any news story concerned with astronomy. If deemed advisable, the guide could list competent writers who have a basic understanding of astronomy and have shown accuracy in its reporting. In addition the supplement will contain a glossary of terms, and descriptions of observatories, the history of each and its directors, public admittance, and the work and location of professional and amateur astronomical societies.

This project can be started by a committee, or even a single enthusiastic and qualified worker, dividing and passing out assignments in small units to authorities in each particular topic, so that each topic may be covered by the man most qualified, and in smaller units impose less work upon each. The labor involved should be expended willingly in consideration of the immediate and ultimate purpose of the project. When the units are returned, the committee will then condense or rewrite them if necessary for editorial uniformity, and assemble the completed work for publication.

After the guide is published it should be revised at intervals to maintain its full usefulness. But once astronomers have discovered its convenience to themselves and the wider public support given their work through greater understanding, they will voluntarily forward material they happen across that has become buried in scientific literature, in order that each edition will be more complete and useful.

ROBERT TOREN.

The Explosive Chemical Hypothesis

I should like to advance a hypothesis which I shall name "The Explosive Chemical Hypothesis," wherein I shall attempt very briefly to explain my conception of some of the processes that operated to build up the vast universe.

We may picture the universe in its earliest stage as a material void in which electric particles roamed aimlessly. In the course of their wanderings they occasionally came in contact with other electric particles, with the result that atoms of hydrogen were formed when the positive and negative particles met under certain conditions as yet unknown.

In time the atoms became more complex, the positive particles forming nuclei of greater and greater complexity, and the negative electrons increasing in number as they revolved around the positive nuclei.

Thus higher and higher forms of atoms developed, beginning with helium with two negative electrons, and gradually arriving at nitrogen and oxygen with seven and eight negative electrons, respectively.

In all probability a point was eventually reached when the hydrogen and oxygen accumulated into a huge body of potentially explosive matter which later actually did explode, and a nebula was born. This nebula may have been the parent of all nebulae, or again, as seems more reasonable, it may have been but one of innumerable smaller ones that formed throughout space mostly in a similar manner. Hence it seems most unlikely that these nebulae came into being at one time or in any definite order but rather formed consecutively at widely separated points and with varying intervals of time elapsing between the individual formations.

While this evolution was proceeding, the nebulae were gradually being transformed from bodies of gas, devoid of stars, into nebulae consisting wholly of stars.

One of the most important questions relating to nebulae is whether they are in recessional motion or not. If they are, then two highly important conditions must be satisfied. First, the distance separating adjacent nebulae must be somewhat of the order of two million light years; and second, the size and mass of each of the various nebulae must be fairly uniform. It is inconceivable that in the outward rush of the nebulae, all could at any time be, and remain, about two million light years distant from their neighbors.

If the nebulae are stationary, then there is no difficulty in satisfying the conditions just referred to. The reason is that gravitational forces were instrumental in robbing space of its original matter, and then concentrating this matter at fixed condensation points. Since the universe is more or less homogeneous, at least as far as its known frontiers, the size and mass of the different nebulae should be quite uniform.

It thus seems reasonably certain that the nebulae are not in rapid recessional motion but are more or less stationary, despite the evidence of spectral displacements.

Now let us examine the law of the red shift. While it is true that it has won the approval of most scientific scholars, nevertheless there remains a certain doubt in the minds of many whether their conclusions are fully justified.

It is known that the red shift is due to increased wave-length, but both loss of energy and recession can bring about increased wave-length. Nevertheless it seems unreasonable that a ray of light traveling a distance of hundreds of millions of light years would not lose energy; and it seems equally unreasonable that a receding nebula could have its velocity so enormously accelerated that speeds of 50,000 miles or more per second could be attained.

We see therefore that both the velocity and energy interpretations are possible. The question remains which of the two is more likely to be true.

I attempted to show that in an expanding universe, uniformity in size, mass and spacing of nebulae would be well-nigh impossible, but could be attainable in a stationary universe.

Admitting for the present the truth of the velocity shift, we may note that speeds of 25,000 miles per second have been recorded by the spectrograph. But

nebulae can be photographed at distances of perhaps five hundred million light years, hence red shifts should be encountered corresponding to velocities of about 50,000 miles per second.

Since velocities, according to Hubble, increase at about the rate of 100 miles per second for each million light years, nebulae at four times the distance of the farthest known nebula would have velocities greater than the speed of light. Jeans has calculated from Hubble's estimate of the mean density of matter in space, that the radius of space is 84,000 million light years, or 600 times the distance of the faintest visible nebula. If his estimate is even remotely correct, then a figure as small as four times the radius of the observable universe is extremely conservative.

If the red shift indicates neither motion nor velocity, then a displacement of the spectral lines greater than any yet observed need cause no astonishment, for it could be interpreted as indicating a universe far greater in extent than had previously been realized.

If the red shift is a velocity shift, then the nebulae are receding and the universe is expanding.

However, there is no need to worry at present whether the universe is expanding or not but, if it should be, our descendants millions of years hence will have just cause for anxiety, for as that unhappy time approaches, cold, darkness, and death will be the inevitable aftermath.

This suggests the question of the possibility of "rewinding" the universe in case it runs down. Is that possible? Jeans says, "no," Millikan, "yes."

I should like to emphasize the fact that some of the simplest elements are the most active chemically, and that when they combine, highly explosive compounds may be produced. That evidently was the process employed by nature to convert a frozen universe into one possessing high temperatures, and to create nebulae, the parents of stars and the grandparents of planets.

At present it appears that any true comprehension of the universe and the creative processes that brought it into being depends in great measure on a proper interpretation of the red shift. It may be wise therefore to heed Hubble's advice and postpone further conjecture on these controversial issues until after completion of the 200-inch reflecting telescope at Pasadena.

This great telescope should penetrate space to such vast distances that soon we may be able to determine empirically whether the assumed recessional velocities of the nebulae are fictitious or real.

L. H. Barnett.

501 West 113th Street, New York City.

General Notes

Readers of this magazine are reminded that there is no issue scheduled for July or for September. The issue for August will be mailed about August 1 and the next one thereafter, about October 1.

Dr. Samuel Herrick, Assistant Professor of Astronomy in the University of California, Los Angeles, has been awarded a Guggenheim Fellowship for the academic year 1945-46, for the study of navigation, especially as it may be modified by the introduction of rocket propulsion.

Bowen Trust—1945 Prizes

The following account of the Bowen Trust Prizes is indicative of the fact that the people of Great Britain are already energetically entering upon a new era of production of scientific instruments and are affording every encouragement to those persons who may have talent for contributing to that end.

Mr. W. Bowen has generously presented to the SCIENTIFIC INSTRUMENT MANUFACTURERS' ASSOCIATION OF GREAT BRITAIN, LIMITED, a substantial capital sum, the income of which he wishes to be devoted towards the encouragement and development of invention, design, research, processes, and manufacturing technique in the Scientific Instrument Manufacturing Industry. The Council of the S.I.M.A. have drawn up a Deed of Trust under which the income from the Trust Fund is to be devoted each year to prizes to be awarded to the Employees of Members submitting papers fulfilling the objects of the Trust.

For the current year the Council have decided to award five prizes to the value of £25 each for—(a) a new invention; (b) an improvement of design; (c) an improvement in manufacturing technique; (d) a new development of new process arising from research. Candidates should furnish a short description of one of the above subjects not exceeding 3,000 words with relevant sketches or diagrams.

The five prizes are offered for a paper on any one of the above subjects affecting or related to a Scientific Instrument covered by one of the following five Sections, to each of which one prize is allocated: *Section 1.* Microscopes, binoculars and telescopes, optical elements and glass, cameras and lenses, cinema apparatus, projection and allied optical apparatus. *Section 2.* Nautical, aeronautical and survey, including geophysical meteorological and fire control (excluding optical) apparatus. *Section 3.* Industrial precision instruments. *Section 4.* Laboratory, Research and Medical Apparatus. *Section 5.* Ophthalmic Lenses.

The competition is open to every Employee of Members of the S.I.M.A. and any employee may compete for the prize awarded under each of the above Sections.

All papers must be submitted to the Secretaries, Messrs. Binder, Hamlyn & Co., River Plate House, 12/13, South Place, London, E.C. 2, by not later than 31st December, 1945. Papers cannot be accepted after that date. It is the intention of the Council to award similar prizes for future years.

The Cleveland Astronomical Society

The annual dinner meeting of the Cleveland Astronomical Society was held Friday evening, May 4, 1945. David Dietz, Science Editor of the Scripps-Howard Newspapers, spoke on "Science of Tomorrow." He pointed out some recent developments in astronomy, physics, chemistry, metallurgy, and medicine and suggested developments in these fields for the future.

With such instruments as the Schmidt-type telescope and objective prism, now doing pioneering work at the Warner and Swasey Observatory, the speaker said much should be learned concerning the Milky Way. It has already been discovered that our galaxy is not unique in size but probably is no larger than our nearest galaxy the Andromeda nebula. More attention should be given to the planets and their satellites in order to make more such findings as the recent discovery of an atmosphere of ammonia and ethane on Titan, one of the moons of Saturn. The streaks radiating from some of the craters on the moon also need study. With the coronagraph added information should be obtained concerning the sun.

In the present war the Pulkowa Observatory in Russia was destroyed by the Germans. The Russians, however, are planning a chain of observatories in their country after the war and expect to train over 700 astronomers so the future of astronomy in Russia looks very bright.

To sum up Mr. Dietz said that tremedous advances have been made in all things needed for the war but pure science has been slowed down. This must again take its proper place when peace comes.

HENRY F. DONNER.

Western Reserve University, Cleveland 6, Ohio.

The Western Reserve University Observatory

The Western Reserve University astronomical observatory, which was originally established in Hudson, Ohio, as the first observatory west of the Allegheny Mountains, will become increasingly active in the immediate future. The 10½-inch refracting telescope, which until recently was the largest telescope in the northern Ohio area will be renovated and put into use for teaching and public views. Professor Henry F. Donner, head of the Western Reserve department of geology and former astronomer with the University of Michigan Observatory in Bloemfontein, South Africa, will be in charge of instruction.

The instruction program will be expanded from one general course to four courses, beginning with the winter term in October. The new course will consist of navigation, practical astronomy, and two courses in descriptive astronomy which will deal with the solar system and the sidereal system. Professor Donner said he plans to announce a series of public nights this fall in which the public will be invited to popular lectures on astronomy and to observe the moon, planets, stars, and nebulae through the telescope. He also plans to improve the micrometer of the telescope with the addition of special electric illumination in preparation for possible resumption of his research on double stars. This research was conducted at Bloemfontein, where between 1927 and 1933 he discovered 1130 of these stars. After preliminary work here, his tentative plans call for a brief leave to make new measurements to see to what extent the stars have changed their position since he last observed them.

Professor Donner is a graduate in electrical engineering of the University of Michigan where he also received his master's degree. After his work at Bloemfontein he returned to the United States and received his doctor of science degree at the University of Michigan in 1936. Before returning, he and Mrs. Donner drove in their automobile the length of Africa from Cape Town to Cairo.

The Western Reserve Observatory established in 1838 at Western Reserve College by Elias Loomis, noted early American astronomer, was the first astronomical observatory in the United States outside the original thirteen colonies. Guest of honor at the dedication was President John Quincy Adams. The original observatory is still at Hudson.

Book Review

Telescopes and Accessories, by George Z. Dimitroff and James G. Baker. (The Blakiston Co., Philadelphia, 1945. 309 pages. $2.50.)

A new and outstandingly different book has been added to the Harvard Series. Since this series has so far dealt with the work and discoveries of the astronomers

it is now fitting that consideration be given to the equipment and tools so essential to the progress of the astronomer.

The authors have covered the broad field of telescopes and accessories in a manner that will prove both entertaining and valuable to all students of astronomy. Those who enjoy Bell's "The Telescope" will find much new material of value in this up-to-date introduction to the field.

An orderly sequence has been followed in that "Light as a Tool" as the first chapter reviews for us in a condensed manner fundamental properties of light from wave-theory to quanta—all with little or no mathematics.

We are introduced to "Visual Telescopes" by a discussion of physiological and optical properties of the eye. Such information is highly valuable and often overlooked. Not only are telescope objectives discussed in a general manner but actual formulae are given for construction of astronomical achromats. The many types of reflecting telescopes are reviewed with authoritative comments as to the good and bad points of each. The importance of properly designed eyepieces is stressed. That there is a limit to what one can see through a given sized instrument is clearly brought out in the discussion on resolving power. The diffraction images given in the appendix are a rare and valuable addition to anyone's library.

"Storing Light—The Photographic Process" is an excellent chapter for the beginner and an interesting review for the advanced student. The photo-chemical action of light, the chemistry of development, and the photographic emulsion are the primary topics of discussion. Amateur astronomical photographers will be interested in 'reciprocity law failure' or the fact that in photographing dim stellar objects an increase in exposure time will not give a proportional increase in film density—the amount of increase of image density varying greatly with emulsion types.

"Photographic Telescopes" contains much new information not found in book form. Standard photographic equipment is reviewed as well as elementary data covering the newer rapid Schmidt and related types of cameras. Certain of these systems are easily four times as fast as the much vaunted expensive miniature cameras lenses. General formulae are presented covering photographic lenses and lens-mirror combinations. The average amateur would require more data than presented for construction but will find this chapter of added broad value to more detailed works on construction such as "Amateur Telescope Making Advanced" edited by A. G. Ingalls. Among systems discussed are many not easily found in texts such as the Schwarzschild, Couder, Ritchey-Chrétien, Maksutov, and the outstanding Schmidt. One of the authors, Dr. Baker, introduces valuable new systems of his own design which have apparent advantages over existing systems in that not only are spherical aberration, coma, and astigmatism eliminated but an *accurately flat* field of as much as 10 degrees may be obtained. Such systems represent a real contribution to progress in photographic telescope design.

"Sifting Light-Spectroscopy" covers the range from the simple objective prism to the image slicer and nebular spectrographs. Diffraction gratings, the slit spectrograph with its resolution and efficiency, and the adaptation of spectrographic equipment to telescopes are discussed in a practical manner. Great strides have been taken in capturing dim light for spectrographic purposes. For such purposes astoundingly fast Schmidt cameras are ground from a large single piece of glass with a resultant light gathering power of over a thousand times that of a simple camera lens.

"Measuring Light" is devoted to both visual and photographic photometry.

The role that the comparatively recent developments in electronics play in precise measurement of light is included with the presentation of photometers and densitometers. The student will be interested in the role the earth's atmosphere plays in measuring light from distant objects.

"Instruments for Solar Research." Our nearest star has yielded many of its secrets mainly through the use of instruments described in this chapter. The principle of the spectroheliograph and spectroheliscope are reviewed with an excellent description of the 70-ft. McGregor Tower Telescope. Many have been waiting to read of the new coronograph which requires a lens of absolute perfection. One tiny speck on or in such lens may ruin the entire instrument's performance. Bands one-tenth as wide as are isolated by the best of filters may be isolated by a quartz monochromator described.

In "Building a Telescope" fundamental principles are discussed but no constructional data given. Here is an opportunity to review interesting details of the 200-inch giant at Mt. Palomar. Reproduced on a small scale with only moderate loss of detail are the famous drawings of Russell Porter presenting structural design of the 200-inch. Accurate telescope drives such as the Gerrish-Hanson and that used at McMath-Hulberg Observatory are discussed along with guiding methods. The authors close with some interesting speculations on the future advance in astronomical research through a proportionally greater investment in research to increase desirable properties of photographic emulsions, rather than to increase instrument size. This point might well be given serious consideration.

To the authors goes due credit for handling a complex subject in limited space in such a manner that all interested in astronomy will find sections which will appeal to his own interests. The reviewer regrets that the authors did not feel free to give specific film and plate recommendations for amateurs in general astronomical photography as such information would have been appreciated by many. The relative newness of the basic Schmidt camera system could have led to a more detailed coverage even at the expense of omitting the specifications of a few older lens designs the value of which is questionable beyond historical interest. "Telescopes and Accessories" is well illustrated, neatly printed and bound, and should be in the library of everyone interested in astronomical instruments and accessories.

HENRY E. PAUL.

Hiawatha To Date*

On a hot and sultry morning
In the wigwam of Nokomis
Sat the little Hiawatha.
Saw the sun rise to the eastward,
Heard the wind among the tree tops.
Then a black, swift, moving shadow
Bit a piece right off the sun's orb.
And the frightened Hiawatha
Whispered, "What is that, Nokomis?"
And the good Nokomis answered,
"Once the moon boy very naughty
Ran and ran around his mother
Hoping that she could not catch him,
Thinking that if it were darker
Then she'd never, never find him.
'It's the sun's fault that she sees me,
It's his bright and shining splendor
Shows the naughty moon boy to her.
I will cover him with darkness,
With night's blanket I'll enfold him,
Then she'll never, never find me.'
Then night's blanket he unfolded,
Right across the sun he spread it
Until all the light was covered;
And his mother left in darkness
Crouched with fear and cried in sadness.
But the blanket would not stay there.
Off it slipped and rolling earthward
Wrapped the moon boy up so tightly
That his mother could not see him.
Just a week it took of struggling,
Straining, tearing at the blanket,
Pleading, praying to the sun-god,
To release him to his mother.
But the sun-god very angry
Said unto the lunar urchin:
'For a period of fast days
I will cover you with darkness
With night's mantle I'll enfold you,
So your mother cannot find you.
When you cry she cannot help you,
When you're sick she cannot nurse you,
When you're starved she cannot feed you,
For in darkness she can't find you.
When again you're feeling naughty
And to eclipse the sun you're tempted,
I may wrap you up so strongly
That no one can ever find you.'
Thus it was he got his phases,
Wrapped within and struggling outward."

M. Grace Smith.

*In recognition of the solar eclipse of July 9.

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